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LECTURES ON GEOGRAPHY

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LECTURES

ON

GEOGRAPHY

DELIVERED
BEFORE THE UNIVERSITY OF CAMBRIDGE
DURING THE LENT TERM 1888

BY

LIEUT.-GEN. R. STRACHEY, R.E., C.S.I.
PRESIDENT OF THE ROYAL GEOGRAPHICAL SOCIETY

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LECTURES ON GEOGRAPHY

LECTURE I

Introduction—Proper scope of geographical teaching—Proposed treatment of the subject—Sketch of the growth of knowledge of the form, movements, and magnitude of the earth—Of the construction of maps and the art of navigation.

WHEN the University of Cambridge resolved in June last to accept the proposal of the Royal Geographical Society to provide a lecturer on geography with the aid of funds to be supplied by that Society, a wish was expressed that the appointment should be postponed until the next year; and that the Council of the Society should endeavour to arrange in the interval for the delivery of

introductory lectures, illustrative of the general character and scope of the instruction in geography suitable for a University course, which it would in future be the duty of the lecturer to impart.

It is by desire of the Council of the Royal Geographical Society that I have undertaken to give effect to this wish of the University authorities.

After careful consideration, I have come to the conclusion that I should direct attention to the subjects with which instruction in geography should deal, rather than to the form in which it should be imparted. I can profess no personal experience qualifying me as a teacher, nor do I think that any useful end would be gained by my offering suggestions as to the method of teaching geography most suitable for students at the University. I cannot doubt that it should be left to the lecturer to select the particular

methods which best satisfy himself, and appear to him most appropriate in relation to the general course of instruction pursued at the University.

That the study of geography should have been recognised by our two great Universities, for the first time in the past year, as deserving a place among the subjects which they undertake to teach, no less than my own presence here for the purpose already stated, are sufficient indications that there have hitherto been no very precise notions of the position of geography as a branch of knowledge susceptible of scientific treatment, nor indeed as to its deserving any special attention apart from its utility in supplying various branches of study with topographical facts. Hence the view of the matter which I shall place before you must be understood as representing only my own personal opinions, though I have every

reason to think that, in substance, the same opinions are held by all those, both in this country and elsewhere, best qualified to be your guides.

Geography has till a comparatively short time ago been commonly viewed rather in the light of its practical value in supplying maps of the world, and of the interest that attaches to the exploration of unknown countries, than in relation to other branches of knowledge, or to the general body of physical science. The more obvious facts for geographical observation are such as strike the least instructed, and the first steps were taken by those who had necessarily little appreciation of the true significance of much that they saw, and were incapable of doing more than collect, and that very imperfectly, the materials which their successors are bringing into a scientific

form. The present generation has almost lost remembrance of the thrilling interest created by the accounts of those geographical discoveries which were among the glories of the past two or three centuries, and the standard volumes of voyages and travels, which delighted the boyhood of their elders, lie forgotten or neglected by the youth of to-day. A new phase of thought has become operative. The connection between geography and physical science is more distinctly recognised, and attention has been especially drawn to the value of geographical knowledge in relation to the ordinary affairs of man, and to the importance of extending such knowledge. There is a clearer appreciation of the influence which geographical features and conditions have exerted on the past history and present state of the several sections of the human race, on the foundation and growth of kingdoms, the

development of industry and commerce, and the spread of civilisation.

The growing sense of the importance of geography in all these aspects has led the Royal Geographical Society for many years past to make continuous efforts to secure for the study of geography a more prominent place in general education; and in order to bring about a more satisfactory system of instruction in our schools, it has sought and obtained from the Universities of Oxford and Cambridge the recognition of this study as a subject that should fall within the range of their teaching, and for which suitable provision will accordingly be made.

In its earliest shape, geography, as I have already observed, concerned itself chiefly with the mere topographical features of the surface, and viewed the earth almost exclusively as the habitation of man. The inquiries it made were directed to the dis-

tribution of the land and water, the positions of the continents, islands, and seas, and of the plains, mountains, and rivers; to the manner in which the land was divided into various countries, and occupied by various nations; to the divisions of countries into provinces, and the situation of the chief cities. The geographer further took note of matters concerning the language, customs, and modes of government of the inhabitants, as well as of the climate and products of the various parts of the earth.

By the gradual extension of observation, and the ultimate adoption of true notions as to the form and magnitude of the earth, the more serious errors of the earlier approximate ideas were corrected, and at length a solid foundation was laid for precise determinations of position, and accurate representation of terrestrial features in detailed maps. And as knowledge thus advanced,

the earlier impressions of travellers, based on the striking differences between distant countries, were supplemented by the perception of coexisting similarities no less remarkable and real. Attention was soon drawn to the peculiarities which persistently characterise the great regions of polar cold and equatorial heat; to the main features of the mountain ranges, the plains, the coasts, and interior of the continents, and of the oceans; to the local and periodical variations of temperature and climate; and to seasons of wind and rain over certain areas of land and sea.

At a later period, the grouping of plants and animals of peculiar structure or of peculiar families in certain terrestrial or marine areas attracted attention, and fresh occasion for observation and thought was found in the circumstances under which such groups varied from place to place, or re-

appeared, more or less completely, under identical or similar forms in widely separated regions, or were more or less strictly limited in number or in respect to the areas over which they were found. Combined with these facts, and studied with them, were the analogous physical peculiarities of the races of man, their languages, customs, and history, varying from one region of the earth to another, yet often having certain common features over large areas.

But before these observations could be viewed as parts of a connected whole, or the true significance of their mutual relations could be properly appreciated, it was necessary that considerable progress should have been made in many special branches of physical knowledge. The ancient sciences of mathematics and astronomy had first to receive the additions which followed the revival of learning in the sixteenth century;

the modern sciences of chemistry and physics, biology and geology, had to be created, and the study of history to be placed on a more scientific basis; and all had to throw their light on the facts brought together from many lands and seas to make a truly scientific conception of geography possible.

Science, whether applied to geography or any other subject, being, in truth, nothing more than well-arranged knowledge, its methods, though first developed by the study of mathematics and of the physical forces of nature, are applicable to all the objects of our senses and the subjects of our thoughts. The foundation of all knowledge is the direct observation of facts; by applying thought to the facts thus observed, we seek through a process of classification and comparison for the causes of which observed phenomena are the results, and

the conclusions thus obtained constitute science.

The aim of geographical science, therefore, is to investigate and delineate the various features of the earth; to study the distribution of land and sea, the configuration and relief of the surface, position on the globe, and so forth, facts which determine the existing conditions of various parts of the earth, or which indicate former conditions; and to ascertain the relations that exist between those features and all that is observed on the earth. Geography is thus ancillary to many other branches of science and learning, for which a knowledge of the relations of such facts or features to the matters with which they deal is essential.

It is evident that the investigation of the causes of terrestrial phenomena, embracing as these do all animate as well as inanimate

nature, requires a knowledge of physical science both wide and deep. But though this be true, it puts no serious difficulty in the way of imparting a thoroughly sound general or elementary knowledge of results already attained, to those who from want of leisure, or perhaps of capacity, are unable to extend their knowledge farther. Nor need such acquaintance with the subject be either superficial or of small value. In every branch of learning the student has to rely on the researches and conclusions of those who cultivate other branches of knowledge. In this respect geography in no way differs, except in degree, from other natural sciences, in all of which it is found that, as knowledge increases, the subject-matters proper to each are necessarily involved with those constituting the special subjects of investigation in other fields. From the great extent of human knowledge, the special branches into

which it is divided have become very numerous; and from the rapid progress in recent times, the difficulty of prosecuting original research in more than a single branch is so much increased, that it becomes continually more important to obtain in a connected form the best possible view of the aggregate result obtained. It should be the aim of scientific geography to supply this, as regards all the phenomena observed upon the earth, so far as they depend upon the material globe and the features of its surface; and to this end I think the teaching of the University should be directed.

It will of course be understood that it is to persons who have acquired a sound elementary knowledge of the subject, such as is demanded by the University in all other branches of study, that the teaching now contemplated will be offered. Objections to including scientific geography in the

course of an ordinary school education, founded on the variety and complexity of the subjects it involves, may without hesitation be discarded. These objections have, in truth, had their origin in the too general absence of scientific knowledge which characterised a generation that had not itself received even an elementary education in physical science, and which stood much in the same position in regard to these matters as that in which men who can neither read nor write stand in regard to the world of letters; such views will no doubt be abandoned as more rational methods of education are adopted.

But it cannot be too emphatically stated that this preliminary training in scientific geography, to be effectual, must be founded on, and combined with, thorough instruction in the general topography of the globe. It appears to me that there is some risk at the

present time of this important consideration being lost sight of, in the reaction that has set in against the merely formal system of teaching geography in our schools, through lists of names, involving little more than ill-directed efforts of memory. I desire, therefore, to express a very decided opinion that no greater mistake can be made in the interests of education than to treat the teaching of elementary geography as supplying the occasion for giving indiscriminate instruction on the various phenomena of which it affords illustrations, and to which it is thus virtually made to appear subordinate. It should be so conducted as primarily to impart an accurate knowledge of the main topographical features of the entire earth, though with a judicious addition of suitable instruction in the physical, economical, and historical characteristics of the various places, whose positions it is important to impress on the

memory of the pupil. The acquisition of really useful knowledge in the necessarily limited time that can be devoted to elementary teaching in geography will assuredly be much facilitated by avoiding trivial details which have neither educational nor other value, but which I fear constitute too large a part of the so-called geography found in our schoolbooks and taught in our schools; and it should never be lost sight of that correct ideas cannot be conveyed to the learner without constant reference to maps, illustrated by frequent use of a globe.

The extended scope of geography, as I have defined it, seems to me to afford no sufficient reason for abandoning that well-known name, and applying to the enlarged field of study that I would throw open any other designation than the old honoured one of geography. I am not to be understood as implying that the study of geography

requires the simultaneous or complete mastery of all the branches of knowledge, physical, biological, historical, or economical, with which it has relation, or that the teacher of geography should attempt to include them in his course of instruction. It is obvious that it is only within certain restricted limits that these subjects come into contact with geography. My contention simply is, that so far as the results obtained through the study of such special subjects indicate an interdependence between the physical features of the earth and what occurs upon it, that relation should be constantly recognised as falling within the province of geography. For reasons which I shall endeavour to develop more fully as I proceed, I am unable to draw any hard and fast line between the material earth and its manifold attributes; and much that is found upon the earth cannot

be properly understood otherwise than in relation to its geographical and topographical features.

I therefore claim for geography, in the sense that I have spoken of it, a place among the natural sciences, as supplying the needful medium through which to obtain a connected and consistent conception of the earth and what is on it, on the importance of which I have already insisted. In this respect the position of geography may be looked on as analogous to that of mathematics, a term to the use of which I never heard an objection, though it is hardly possible to limit the extent of its range; and, following this analogy, it might be convenient to give some such designation as Applied Geography to the outlying portions of the subject which connect it with other independent branches of knowledge.

In proceeding now to place before you in a succinct form a connected view of the matters lying within the range of scientific geography, and which would supply the subjects for University teaching, I shall first direct your attention to the manner in which our knowledge of the form and magnitude of the earth has been acquired, and the gradual extension of geographical exploration has taken place. I shall then pass to that part of the subject which treats of the manifold phenomena exhibited by our planet and its aërial envelopment, all of which are determined, first, by the action of the great physical forces, attraction and heat, controlled by the earth's figure and its movements on its axis and round the sun; and secondly, by the distribution of the sea and land, and the configuration of the surface of the latter above and below the sea-level. Finally, I shall consider the rela-

3 tions of vegetable and animal life with past and present terrestrial features, and the influence of geographical conditions on man.

The intimate relation between geography and astronomy is at once indicated by the dependence of the geographer on the latter science for a knowledge of the methods of determining the magnitude and true form of the earth, and of ascertaining position on its surface. It is of the highest interest to contemplate how man, many centuries ago, with instrumental appliances of the rudest description, and with no other aid than his wonderful reasoning faculty, discovered by observations of the apparent motions of those heavenly bodies from which an impassable gulf divides him, the figure and dimensions of the globe on which he stands, of which he had as yet seen but a very small part; and

how he thence extended this knowledge to the magnitude, the distances, and the laws that regulate the movements of all parts of the planetary system to which the earth belongs.

Leaving the obscure origin of astronomical conceptions to be sought for in Babylonia or Egypt, it is to Greece that we turn to find the first definite scientific opinions on these subjects. Thales of Miletus, 640 years before the Christian era, already taught that the earth was a sphere. To his successor, Anaximander, is attributed the invention of maps; and Pythagoras, the disciple of Anaximander, is believed to have suggested the true doctrine of the revolution of the earth on its axis and round the sun, though this conception, which is described by Cicero in very clear language as having been adopted by the school of Pythagoras established in the Greek

colonies in Italy, dropped out of sight for centuries.

Eratosthenes, of the Greek school of Alexandria, in the third century before Christ, executed what was probably the first measurement of the magnitude of the earth, adopting for the purpose, in principle, the method still in use. He observed the sun's meridional altitude at the time of the solstice both at Syene and Alexandria, which are nearly on the same meridian, and thence deduced the angular distance of the zeniths of those two places, which represented the arc of the terrestrial meridian between them; from which, knowing their distance from one another measured in stadia, the standard in use in his day, he calculated the length of the entire terrestrial meridian, and the earth's radius, in terms of his standard, our ignorance of the exact value of which, however, prevents our knowing what degree of

accuracy he attained. This astronomer also first determined the obliquity of the ecliptic, or the angle made by the plane of the earth's equator with that of its orbit, thus supplying the key to the cause of the succession of the seasons of the year.

Hipparchos, of the same school, who lived a century later, was the greatest of the Greek astronomers, and his additions to the science were truly remarkable. He discovered the precession of the equinoxes, or the periodical change of direction of the earth's axis from east to west, in the opposite direction to its motion in its orbit; also the eccentricity of the sun's apparent orbit, and the inequality of its apparent motion, and he calculated its distance from the earth. To him are due the methods of calculating triangles, spherical as well as rectilinear, the system of fixing geographical position by means of latitude and longitude, and the method of

calculating longitudes from eclipses of the moon.

An interval of 300 years followed which records little progress calling for notice. It is, however, marked by the rectification of the Roman calendar, by the introduction of the leap year, carried out by Julius Cæsar, with the aid of an astronomer of the school of Alexandria; and the recognition of the dependence of the tides of the ocean on the apparent movements of the moon and the sun, attributed to Posidonios.

Ptolemy, about 150 A.D., was the last eminent man of this school. He adopted the sound principle of constructing geographical maps or charts from latitudes and longitudes, determinations of which for all known places he tabulated with this object. But these data were to a great extent vague and inaccurate; and his results, though given a scientific form, did not rest on any scientific

basis of fact. He is better known, however, by his treatise on Astronomy, the Μεγάλη Συντάξις, which long continued to be the great authority on such subjects, and which caused his name to be given to the conceptions of the solar system it contained, though these were really due to his predecessors. He taught that the sun, moon, and planets moved round the earth in what is known as a system of epicycles, the several bodies revolving in circular orbits round centres, which in turn revolved in circles round the earth—a view which was accepted till the time of Copernicus.

From the time of Ptolemy until the sixteenth century, a space of 1400 years, no progress of any importance was made towards the formation of more correct ideas of the relation of the earth to the celestial system to which it belongs. The study of astronomy was revived, however, in the ninth century

after Christ, among the Arabs. Al-Mamun, the son of the famous Khalif, Harun-al-Rashid, caused the treatise of Ptolemy to be translated into Arabic, in which shape it became known as the Almagest; he also undertook the measurement of a degree of the meridian on the plains of Mesopotamia; and it was mainly through the teaching of the schools established by the Mahommedans in Spain, and thence transmitted to Italy and diffused in Europe, that the knowledge already acquired was retained and eventually so vastly extended.

The revival of learning, and the material progress of the States of Europe during the thirteenth and subsequent centuries, gave a fresh and powerful impetus to the spirit of investigation and exploration that had so long remained in abeyance, and were followed by a remarkable series of scientific and geographical discoveries.

A little after 1500 A.D. Copernicus put forth the view—this time to be finally accepted—that the earth and planets move round the sun. The discoveries made almost simultaneously by Galileo and Kepler at the commencement of the seventeenth century completed and corroborated this theory, and so opened the way for that explanation of the whole series of astronomical phenomena by the operation of the law of universal attraction, which is due to the genius of Newton, and which was published in the *Principia* in 1687.

A great impulse was given to precise geographical knowledge by Galileo's invention of the telescope, and by the application of the pendulum to clocks by Huyghens and of spiral springs to watches by Hooke. The employment of these instruments supplied the means for obtaining greatly increased accuracy in astronomical and geodetic observa-

tions; while the invention of logarithms by Napier, 1614, was a most important aid to progress by facilitating all computations. More exact determinations of the dimensions and figure of the earth soon followed.

The measurement of an arc of the meridian near Paris by Picard, 1669, with the help of improved instruments furnished for the first time with telescopes, led to attempts to verify by actual measurements Newton's theory of gravitation, as applied to the form of the earth and its attractive force.

For this purpose the French Academy, in 1735, sent out expeditions to Quito on the Equator, under Bouguer and De la Condamine, and to Lapland within the Arctic circle, under Maupertuis. The measurements thus obtained were supplemented by Lacaille at the Cape of Good Hope in 1752, and those originally made by Picard were repeated and extended. The

operations thus carried out finally established the fact of the earth's ellipticity, by means of combined geodetic and pendulum observations; the former showed the smaller length of a degree of the terrestrial meridian at the Equator and its gradual increase in advancing towards the poles; and the latter proved the increase of the force of gravity at the surface with increase of latitude, as indicated by the time of vibration of the pendulum, which was found to increase or diminish as the distance from the earth's centre is greater or less. Nothing then remained to be done in this direction but to attain results of greater precision, by the employment of better methods in detail, and of improved instrumental appliances.

The geodetic operations commenced by the French Academicians were extended to England in 1783: since which time many other arcs of the meridian and of circles of

latitude have been measured in Europe, Asia, and America; and geodetic surveys of great accuracy have been extensively carried out, forming the basis of most modern maps.

The dimensions of the earth, adopted by our latest, and I believe our best authority, General Clarke, are as follows:—Polar radius, 3949.79 statute miles; equatorial radius, 3963.30 statute miles; ellipticity, 13.51 statute miles, or $\frac{1}{293}$. The radius of the mean sphere approximating most closely to the ellipsoid is 3959 miles, its diameter is very nearly 7920 miles, and the length of a degree on such a sphere is 69.09 miles.

The exact determination of the figure of the earth, and of the relative positions of places on its surface, on which the accuracy of all delineations of its features in maps depends, is a task involving many difficulties and calling for rare abilities in the geodetic

surveyor. It is not likely that the results obtained from the measurements already made will be found to require any but very slight correction hereafter, and future variations will probably represent little more than discrepancies due to actual irregularities in the figure of the globe, which often bear a by no means unimportant ratio to the deviation of the elliptical from a spherical form, the difference between the equatorial and polar radii of the terrestrial ellipsoid being only about 13½ miles.

Among the causes of the uncertainty that attends such measurements, other than those just referred to, one specially calling for notice is the variation of the direction and force of gravity, due to local attraction by mountains, or to variations in the density of the interior of the earth. As variations in the force of gravity depend not only on distance from the centre of the earth, but also

on the greater or less density of the interior, difficulties arise in distinguishing to which of these two causes the effects are due. The observed facts have led to the conclusion that gravity is invariably greater at coast than at inland stations, and greater on islands than on the coasts of continents. Moreover, while this indicates greater density below the ocean-bed, there is reason to think that the density is reduced among mountains, for the deviations of the plumb-line from the vertical caused by them are found to be considerably less than would be due to local attraction, unless the mountain density be less than that of the earth's crust below. It has been argued, with apparent reason, that this varying density may be due to an actual contraction and condensation of the ocean-beds, in some degree corresponding to their depth; and to an expansion and attenuation of the land-masses corresponding to their elevation.

The want of regularity in the earth's figure is not confined to the solid surface, but necessarily extends to the ocean surface, which must be affected by the local variations of attraction, though the exact amount of the disturbances will apparently remain unknown, at least to a great degree. It has been calculated that, under certain assumed conditions as to the relative density of the sea and land, the effect of the absence of land between the Indian Peninsula and the South Pole, combined with the attraction of the Himalaya Mountains and the high land of the Peninsula, would be to raise the level of the sea surface at Karachi as much as 500 feet above that at Cape Comorin. But it is possible that the smaller density of the land above the sea-level, and the greater density below the ocean bottom, may wholly or partially compensate for the irregular distribution of the land and sea, so that the ocean-level may

not in fact be thus disturbed. The conclusion however, cannot be avoided, that measurements of heights above the sea-level as commonly stated, though fairly comparable one with another over a limited area, are subject to no little uncertainty if regarded as absolute quantities referred to the ideal sea-level of the mean terrestrial ellipsoid.

The conceptions of the Greeks as to the form of the earth, and the manner of determining position on its surface, were for many centuries very imperfectly applied to the preparation of maps. Methods of calculating latitude, and instruments suitable for applying these methods, were comparatively soon devised. The difficulty of obtaining differences of longitude was far greater, and could not be completely overcome until correct clocks were constructed. The determinations of latitudes were slowly

accumulated, while those of longitude long remained extremely imperfect. So far as is known, there would appear to be only one map now existing attributable to the period of Imperial Rome, referred to the third century, though itineraries in a graphic form were in common use. The Arabs added something to the art of map-making between 800 and 900 A.D. The use of the magnetic needle for navigation is believed to have been first generally adopted in Europe about 1200 A.D., and it was about the middle of the thirteenth century that "compass" maps were devised, the earliest representing the Mediterranean, showing the bearings between various maritime stations, and indicating the courses to be followed in sailing from one port to another. The idea current in the Middle Ages, that the inhabited earth was circular, much impeded progress in the preparation of correct maps. This has

destroyed much of the value of the great map of Fra Mauro, 1459, now in the Ducal Palace at Venice. The most remarkable and almost unique attempt to represent the then known facts of geography, without such theoretical distortion, is the Catalan Map in the French National Library, dating from 1375. Lines of latitude and longitude are believed to have been first introduced upon maps by the Portuguese, when voyages in the Atlantic began to be frequent, probably between 1400 and 1500. The earliest printed map appeared in 1460, following the invention of printing, and by 1500 maps had become common. The first maps seem to have been brought to England in 1489, and almanacks were first printed in 1470.

The construction of charts on Mercator's projection, invented by Gerhard Kramer in 1537, and improved by Wright, who substituted for the original approximate method

a strictly correct graduation of the arcs of latitude along the lines representing meridians, may be regarded as the commencement of scientific map-making, and it rendered possible a very great advance in navigation. The charts thus drawn were adopted by navigators generally by 1600, and have continued in use without modification to the present time, nor does this system of projection seem to be susceptible of improvement for the purposes of the seaman.

Treatises on navigation first appeared about 1537 in Portugal, and 1580 in Hungary, and were introduced in England by Wright in 1600, in which year also the use of the log for measuring the speed of ships was invented, and a knowledge of the variation of the compass was acquired soon after. Up to this time the only instruments used at sea for astronomical observations had been the cross-staff and astrolabe; with the

former, angular distances from the horizon could be obtained only by looking in two directions, and with the latter by help of a plummet. The invention of the reflecting quadrant by Hadley in 1730, when perfected by the application to it of the telescope, the vernier, and the accurately divided circles which the progress of mechanical art provided, and when further supplemented by improved time-pieces, placed at the disposal of the navigator all that he needed to enable him, in fixing his position at sea, to apply the exact methods of computation with which the astronomers supplied him. Maskelyne in 1763 perfected the method of obtaining the longitude by measuring distances of the moon from stars, and the publication of the Nautical Almanac, also due to him, commenced in the year 1767. It was in 1760 that Harrison received the sum of £20,000, for the successful construction of a chronometer suitable for use at

sea, and capable of supplying a reliable measure of changes of longitude by means of a comparison between its indications and local time. For this, great accuracy was essential, a difference of $3\frac{1}{2}$ seconds of time corresponding to a distance in longitude of about one statute mile at the Equator, and half that distance in latitude 60°. In this manner was attained the long-sought solution of the most difficult problem of navigation, to obtain which large rewards were for many years publicly offered.

The science of navigation was thus created and matured, by the help of the discovery of the telescope, and the progress of mechanical art, which produced instruments capable of measuring angular distances and time with great precision. It has supplied the means by which in our time the skilful mariner passes to the most distant parts of the globe in complete security, at a speed which now makes

every part of the habitable seaboard, however remote, more accessible than were many places in our own islands hardly a century back.

But to admit of such triumphs, the accurate representation of the features of the earth's surface by charts or maps was essential; and the representation in a rigorously accurate manner on a plane, such as a sheet of paper, of a figure drawn on a spherical surface, being necessarily impossible, much ingenuity has been applied in devising the best methods for approximating to the truth.

Reference has already been made to Mercator's projection of the sphere. On this system the meridians are all drawn parallel to one another, the pole being conceived to be infinitely distant from the Equator, and the circles of latitude being represented by straight lines parallel to the Equator and at right angles to the meridians. The gradu-

ation of the meridians is so arranged that everywhere on the chart the proportion between the length of a degree of latitude measured on the meridian, and of longitude measured on the lines representing circles of latitude, is the true proportion as it actually subsists on the globe. It follows from this construction (and this constitutes its special utility to the seaman), that a straight line drawn in any direction on the map represents a course on the globe which everywhere cuts the meridians at the same angle; so that the course of a ship may at once be laid down upon the chart on any given bearing, and will be correctly represented by a straight line drawn with the required inclination to the meridian through the place from which the ship starts. Upon any known course and for a run of any given length, the difference of latitude between the point where the run began and that where it ended, may be obtained by the

help of tables prepared for the purpose, and thus the ship's place at the end of the run may readily be marked on the chart.

For other purposes than those of navigation this projection is likely to be extremely misleading. The degrees of the meridian, instead of being uniform in length, as they would be on any scale to which maps can be drawn, appear to increase with the latitude, till at the pole they become infinite; while degrees of longitude measured on the small circles of latitude, instead of diminishing in the higher latitudes, and vanishing at the pole, are made to appear constant, and everywhere equal to degrees of the Equator. Hence the magnitudes of all parts of the map in the higher latitudes are very greatly exaggerated in relation to the equatorial regions, which alone are in proper proportion, and the non-convergence of the meridians leads to great misrepresentations of true relative position.

This projection must indeed be looked on rather as a diagram prepared for a special purpose than as giving even an approximately true representation of the earth's surface. In this respect, however, it differs only in degree or manner from other projections in use, by aid of which attempts are made to represent large areas, such, for instance, as that employed to exhibit the earth in two hemispheres. Some projections are in the nature of perspective drawings, and are therefore necessarily faulty in the sense of their topographical accuracy.

On the whole, the method of projection or development known as the conical is the easiest to follow, and usually open to fewest objections. In this the surface of the part of the sphere to be represented is supposed to be covered by a conical surface, which cuts the spherical surface along two small circles of latitude inter-

mediate between the upper and lower margin of the area to be dealt with. Places on the sphere are then represented on the conical surface by the intersection of that surface with lines drawn from the earth's centre through those places. The meridians appear as straight lines converging to a point, and the circles of latitude as arcs of concentric circles everywhere intersecting the meridians at right angles. The supposed conical surface being then conceived to be unrolled, supplies a map on a plane in the usual form; while if bent into its proper conical shape it will represent, within the limits that are possible for a flat surface, the true relative positions of places on the spherical surface.

Many more or less complicated methods have been devised for adjusting the supposed conical surface to the portion of the sphere to be represented, in the manner

which shall lead to the least possible distortion or local exaggeration. But there is not much, if any, reason to prefer any of these to an arrangement which assumes the cone to cut the sphere in two places, respectively half-way between the extreme north and south ends of the central meridian and the centre point of that meridian.

A convenient modification of this development is the following:—The degrees of latitude are to be set off along the central meridian upon any desired scale, and of uniform length, and the meridian-lines are then to be drawn so that arcs of longitude measured along the circles of latitude described through the points where the cone cuts the sphere shall have their true length in relation to the arcs of latitude. If L and *l* represent respectively the latitudes, expressed in degrees, at which the conical surface is supposed to intersect

the sphere, then the distance of the centre of the concentric circles of latitude to be drawn on the map, measured from latitude L along any meridian, and expressed in degrees, will be

$$(L - l) \times \left(\frac{\cos L}{\cos l - \cos L}\right).$$

On such a projection the aggregate error is a minimum; distances measured from north to south would everywhere be correct, while the errors in measurements from east to west on a map embracing the whole of England would not exceed 14 feet in a mile in latitude 50°, or 17 feet in latitude 60°, both being in excess of the truth. In a map of Europe, extending from latitude 70° to 35°, the error in measurements from east to west would be about five per cent at the top of the map, and three per cent at the bottom, both in excess, and on the middle latitude about one per cent in defect.

For maps of the Polar regions another projection is most convenient. The meridians converge to the pole, and the circles of latitude are drawn concentrically around the pole. Degrees of latitude are measured uniformly along the meridians. The errors of distances measured on the circles of latitude are about three per cent in excess at latitude 60°, and about ten per cent at 45°.

Much still remains to be done in perfecting the method of representing mountain features on maps. The conception of indicating the relief of the surface by contours drawn along lines of equal altitude above the sea-level is understood to be due to Laplace, and is admirably well suited for many purposes. The ordinary system of shading with short transverse lines is difficult of execution, and fails properly to distinguish such features as elevated plateaus. A method, recently adopted, of indicating altitude by a grada-

tion of shades of colour, the borders of the shades following suitable contour-lines of level, appears to furnish the best solution of the difficulty yet proposed, for maps to which it is possible to apply it.

And here let me dwell for a moment upon the very great practical value of those compendious contrivances for conveying information to the mind, diagrams and drawings, which are little, if at all, less valuable than written language. Their special power consists in bringing clearly within the reach of apprehension, at the same moment and in suitable juxtaposition, numerous objects interdependent but different, and so producing an intelligent connected conception of the whole, often without effort, and always with a clearness that no verbal description could secure. I desire to invite particular attention to this subject, feeling assured of the high utility of the

graphical representation of facts in dealing with the many complicated phenomena that present themselves to the scientific student of geography. To comprehend maps or diagrams is within the reach of all, and a certain fair facility for making them may be acquired as readily as the art of writing. Man is distinguished from all other animals by the faculty of speech; he is also the only drawing animal. These faculties correspond with the two ultimate modes by which it is possible for ideas to be communicated apart from actual experience, and he who possesses and exercises both, vastly increases his power both of acquiring and imparting knowledge.

LECTURE II

Progress of geographical discovery—Operation of physical forces on terrestrial phenomena—Influences of the form and movements of the earth—Terrestrial magnetism—Relation of geology to geography—The terrestrial sphere and its interior.

HAVING thus followed the growth of our knowledge of the earth's figure, of the art of navigation and the preparation of maps, I pass on to notice the parallel onward course of geographical discovery.

In many other branches of science the successive steps by which knowledge has been advanced bear little on the ultimate results arrived at, which are complete in themselves, and constitute a body of fact having no necessary relation to the persons

by whom, or to the manner in which it was collected. But geography presents itself in a different light. Geographical discovery, followed as it immediately was by political movements affecting great masses of mankind, assumes an extremely important part in the history of man, there being, indeed, no country which has not been influenced by the course of discovery during the last 400 years; and it can hardly be doubted that had Columbus, for instance, made his famous voyages under the flag of England instead of Spain, which seems to have been at one time possible, the history of modern Europe would have been very different.

The study of geography, like that of astronomy, first took a definite shape in Greece. The earliest geographical conceptions, upon which the gradually increasing knowledge of the civilised world was engrafted, were necessarily based on ideas

of position in relation to the locality where the ancient geographers lived and wrote, namely, the eastern end of the Mediterranean Sea; here the Phenicians, the earliest of European navigators, had established the centre of their commerce, extending their voyages to the Red Sea and Persian Gulf on the east, and the coasts of Britain on the west. Herodotus, writing 450 years before the Christian era, may be taken as the exponent of the earlier forms of Greek geography. The junction of the Mediterranean with the Atlantic was then known; ideas of the North and West of Europe were vague; the form and position of the Caspian were fairly ascertained; the descriptions of India did not extend beyond the Upper Indus; and the coasts of Asia seem to have been unknown beyond the Persian Gulf. Herodotus speaks of the circumnavigation of Africa, but it may be

doubted whether this was more than mythical. It is a curious illustration of the result of absence of effective publication, that though Herodotus had a just general notion of the form of the Caspian, Ptolemy entirely misconceived it, and it was not recovered till within the last 200 years.

Alexander's expedition, 330 B.C., passing through Asia Minor, Persia, and Bactria, reached the Indus, where his traces and those of his successors are still to be found, and the Greek names given to some of the great geographical features of the country he passed through are still in use on our maps. Of the Greeks who accompanied him some went into India Proper; while Nearchus on his return followed the coast from the Indus to the Persian Gulf, and ascended the Tigris beyond Baghdad. The successors of Alexander's captains in the Bactrian kingdom, which they founded, extended their knowledge

to Eastern India, and one of their envoys visited Pálibothra, believed to be Patna, on the Lower Ganges. About the same time Carthage, originally a Phenician colony, which had become the most important maritime power in the Mediterranean, appears to have sent expeditions along the western coast of Africa, reaching perhaps to the Equator, while its ships also visited France and are said to have sailed round Britain. The trade between Egypt and the east was maintained from Berenice in the Red Sea, and other ports at the mouth of the Persian Gulf, of which Hormuz was the mediæval representative, and through them the commerce with Europe was carried on.

Up to the Augustan age the only additions to geography were obtained through the Roman conquests in Western and Northern Europe. In the time of Pliny the coasts of Asia had hardly been described

with certainty beyond the mouths of the Ganges, and only vague conceptions of China had been formed. These ideas had become more defined, and extended to the Malay Peninsula, Sumatra, and Java, by the time of Ptolemy, 150 A.D.

Till the end of the twelfth century the further progress of geographical, like that of all other branches of knowledge, was very inconsiderable. Something was done by the Arab geographers in the early period of the growth of Mahommedan power, and something by Norwegian Vikings whose voyages extended to Iceland, Greenland, and eventually to the coasts of North America. But in the thirteenth and following centuries, when the civilisation of Europe was becoming consolidated, a more active spirit of enterprise was gradually awakened.

The formation of the powerful republics of Venice and Genoa, and the spread of their

commerce under the stimulus of many causes, of which the Crusades may be reckoned as one of the most prominent, was followed by a development of maritime habits, knowledge, and enterprise among the nations bordering the Mediterranean, which was destined to produce great results.

The institution of the orders of friars, the desire to spread Christianity, and the terror produced by the incursions of Jenghiz Khan into Eastern Europe, were followed by journeys, of which one of the most remarkable was that of the monk Rubruquis, 1253 A.D., into Central Asia. The growth of commercial activity sent forth the Polos, 1265, on similar expeditions, which extended to Mongolia and China. The friar Odoric, 1320, visited Persia, Western India, Sumatra, and Java, as well as China, returning by Tibet, and was the first European to reach Lhassa. Thence he travelled by Cabul and

Tabriz to Venice. His accounts are unquestionably the basis of much that is found in Sir J. Mandeville's travels, which there is great reason to think are mainly, if not wholly, fictitious.

Among the travellers of this period should also be specially mentioned Ibn Batuta, an Arab of Tangier, 1325-55, who, after visiting Egypt and Arabia, went through Persia, Afghanistan, and India, whence he was sent by Muhammad Toghlak, then king of Delhi, on an embassy to China. He travelled thither by sea down the west coast of India to the Maldives and Ceylon, and on through the Eastern Archipelago to China. His journeys are reckoned to have extended over 75,000 English miles.

Thus we are brought to the eve of that great series of voyages which are the glory of the fifteenth and sixteenth centuries, and among the most remarkable events recorded

in history; they opened out the way to Eastern Asia round the Cape of Good Hope, and added in the west a new continent to the known world.

The honour of taking the initiative rests with the Portuguese. Soon after 1415 a course of maritime exploration was entered on, and continued for many years under Prince Henry, which led to the successive discoveries of Madeira, the Azores, the Cape de Verd Isles, and by 1484 extended along the west coast of Africa beyond the Equator. In 1486 King John sent out Diaz to endeavour to reach India by sea, the belief having become established that this could be done by passing round the continent of Africa; but this expedition advanced little beyond the Cape of Good Hope.

Eleven years later, and two years after Columbus had returned from his first voyage, Vasco da Gama, the largest of whose ships

did not exceed 120 tons burden, doubled the Cape of Good Hope, and passing along the east coast of Africa to Mozambique and Mombasa, crossed the Arabian Sea and arrived on the western coast of India, near Calicut, in 1498 A.D. Cabral in 1500, on his way to India by the same route, discovered the coast of Brazil. Many similar voyages followed, and in the course of the next few years the western and eastern coasts of Africa, and the shores of the Arabian Sea, were explored; the islands of St. Helena, Tristan da Cunha, Madagascar, Socotra, Bourbon, and Mauritius were made known; and the Portuguese under Albuquerque had established themselves at numerous places along the coast of Arabia and India, making Goa the seat of their government. Their advance to Malacca immediately followed, and they explored Sumatra, Java, and the much coveted Spice Islands or Moluccas, their

ships reaching China for the first time in 1514. Their settlements at Macao, near Canton, date from 1537. Thus in less than fifty years from the discovery of the Cape of Good Hope the Portuguese had opened out the whole of the coasts of Africa and Southern Asia as far as China, as well as a large part of the Eastern Archipelago.

Almost simultaneously, Spain, adventurers from which had already reached and occupied some of the Canary Isles, entered on a course of discovery and conquest still more remarkable. After the final triumph of Ferdinand over the Moors, the perseverance of Columbus was rewarded by the acceptance of his proposals to attempt to reach the Indies by sailing across the Atlantic, in the hope of thus finding a shorter route than that which the Portuguese were seeking round the continent of Africa.

It was in 1492 A.D. that Columbus, guided

by a truly scientific course of induction, for the first time so applied by any navigator, embarked on the first of the celebrated voyages which resulted in the discovery of the land which was at the outset supposed to be the eastern shore of Asia; an error largely due to mistaken reliance on Ptolemy's vastly exaggerated estimate of the longitude of those shores, and on distances deduced from the itineraries of Marco Polo and other travellers. From the first newly-discovered islands, ever since known as the West Indies, advances were soon made to the neighbouring coasts of the continent along the narrow isthmus between the gulfs of Darien and Panama, and the discovery of the Pacific Ocean by Nunez de Balboa followed in 1513. The accounts of this were received with an interest little less keen than that which had followed the discoveries of Columbus, indicating as it did the existence of another

great ocean still intervening between the new continent found by Columbus and Eastern Asia. The exploration of the Gulf of Mexico, and the entry of Cortez into that country in 1520, and its final conquest, followed in rapid succession. In 1521 the first advances were made along the shores of the Pacific; Peru was first seen in 1526, Pizarro landed there in 1531, and the whole of that country and Chili were shortly added to the Spanish kingdom.

Meanwhile the discovery of Nunez had led to the despatch of an expedition under Magellan, a Portuguese who had sailed under Albuquerque, but had entered the service of Spain in order to undertake the enterprise of reaching the shores of Asia by passing round the extremity of the new continent, and crossing the lately-discovered Pacific Ocean. This object he successfully carried out. The Straits now called after

Magellan were passed in 1520, and first the Ladrone Islands and then the Philippines were discovered, where Magellan was killed in a conflict with the natives. His companions, however, continued their voyage, and passing through the Indian Archipelago, where the Portuguese had already established themselves, one of the ships, which alone survived, reached Spain again in 1522, having for the first time in the history of man accomplished the circumnavigation of the globe.

The enterprise of Spain thus completed that great work of maritime discovery in which Portugal took so honourable a share, and which in a period of less than fifty years had led to the acquisition of a fairly accurate knowledge of the distribution on the surface of the earth of the principal areas of land and sea in their main features.

It was soon after the commencement of this course of discovery, 1494, that an agree-

ment was come to by Spain and Portugal, for the division between the two nations of the newly-discovered parts of the world. This was submitted to the Pope for his sanction, and a Bull was accordingly issued by Alexander VI, which declared that a line should be drawn from pole to pole, across the globe, 100 leagues, (afterwards removed to 370 leagues,) west of the Azores and Cape de Verd Islands, and that all newly-discovered territories to the east of this line should fall to the share of Portugal, all those to the west, to Spain. This arrangement determined the direction given to the voyages undertaken by the two countries. The line proposed is nearly on the 50th meridian west of Greenwich, and the corresponding line in the other hemisphere is on the 130th meridian east. Its adoption as a boundary served to confirm Portugal in its occupation of Brazil; but subsequently led to a conflict as to the right

of Spain to the Philippines and Moluccas which lie along the 120th meridian. It is a singular circumstance that the Pope was once more referred to, only a year or two ago, to arbitrate on the occasion of a dispute with Germany as to the territorial rights of Spain over the Caroline Islands; and, if I mistake not, the Bull of Alexander was adduced as evidence in the discussion.

Before the end of the sixteenth century the exploration of the western shores of the North Atlantic as far as the polar seas had been completed by English and French sailors. The earliest English voyages of discovery are those of Cabot, believed to have been a Venetian, who had settled at Bristol in the reign of Henry VII. In 1494, when in search of a north-west passage to the Indies, he reached Newfoundland, and his sons sailed along the American coast as far south as Florida, already known through the

Spaniards. Frobisher and Davis, 1576-85, explored Labrador and the west coast of Greenland, and entered the bay now called after Baffin, who in 1616 penetrated still farther, and reached lat. 78° N., but only to find the way onward blocked with ice, and impracticable.

In the latter part of the same century the Spaniards sent several expeditions from Peru across the Pacific, still seeking the Philippines and far-famed Spice Islands, and for the first time visited various groups of islands in that ocean, the Marquesas, the Society Islands, and the New Hebrides. Drake, 1577, passing through Magellan Straits, extended his explorations up the western coast of America as far as California, and for the second time accomplished the circumnavigation of the earth.

So far as the great geographical features of the globe are concerned, all that

remained to be done was to define the position and extent of the continent of Australia, and this was virtually accomplished by the Dutch in the next half century. The voyages of the Dutch into the Eastern Seas began about the year 1600, and this enterprising nation by degrees displaced the Portuguese from their possessions in the Eastern Archipelago, establishing themselves in their place, and in this position they still remain. A Dutch expedition bound for the Eastern Islands first determined, 1616, the true extremity of the South American continent by rounding Cape Horn. The northern and parts of the western coasts of Australia were explored by the Dutch in 1627. In 1642 Tasman sailed round Australia; he first discovered what he named Van Diemen's Land, but which is now called Tasmania after him, believing it to be a portion of the mainland, and subsequently New Zealand,

whence he passed on through the Fiji and Solomon groups, by New Britain and round New Guinea. In 1606 Torres, a Spanish commander, in a voyage from Peru, had already reached the north-east angle of Australia, and, passing through the straits which now bear his name, had sailed up the south-west coast of New Guinea, thus showing that the extreme north-eastern limit of Australia had here been reached.

It is worthy of notice that all the voyages across the Pacific were directed almost along the same line, from the extremity of South America towards New Guinea, doubtless with the object of reaching the Moluccas or Philippines, which, from a belief in the wealth there to be acquired by commerce and plunder, had become the centre of attraction to all classes of adventurers, whatever flag they flew; and to this cause may be attributed the circumstance that the geography of Aus-

tralia and the Northern Pacific was not made known until a comparatively late period.

With the latter part of the seventeenth century we reach the period when a spirit of commercial enterprise in a great degree replaced the old spirit of adventure and love of conquest, which had stimulated the earlier voyages of discovery. Concurrently with this change a great development of scientific knowledge had taken place, and expeditions, mainly for purposes of scientific discovery and investigation, began to be despatched to many distant or little known parts of the earth. Of the results of these it is only necessary to refer specifically, first, to the discovery by Behring, in 1728, of the straits separating Asia from America, through which Cook also, fifty years later, after traversing the Pacific from south to north, penetrated as far as lat. 70° 40′ N., when he was stopped by ice; and, second, to the fact established

by the last-named great navigator, that, whatever land there may be around the South Pole does not extend beyond the Antarctic circle.

A position had by this time been reached in which the further progress of geography chiefly required a more exact delineation of details, and the extension into the interior of the great continents of the explorations which at first had to so considerable an extent been confined to the sea-coasts. In this labour the services of France and England were most conspicuous until the commencement of the present century. As we approach the present time, there has been a general co-operation among all civilised nations in the advancement of geographical knowledge, and the scientific value of the work done by explorers both by land and sea became greater, as the full extent of the requirements of scientific investigation were more completely realised.

So thorough is the success with which these labours have been prosecuted that it would be impossible for me here to describe what is known of the earth, otherwise than by pointing to what is still unknown, and this may be summarised in a very few words.

Besides the interior of Borneo and New Guinea, and the portion of Central Africa where Stanley is for the present moment lost to view, no considerable part of the earth's surface is unexplored, with the exception of the polar regions, which have till now proved inaccessible. The maps of the interior of Africa now supply trustworthy representations of a vast system of rivers, lakes, and mountains, till recently wholly unknown to the civilised world, and what remains to be done is little more than to fill in the details of well-ascertained outlines. Australia has been crossed and recrossed in many

directions. The darkness which so long enveloped Central Asia has been entirely cleared away, and though parts of Tibet are yet to be visited, the true nature of that remarkable country, and of the central plain lying between it and Siberia is completely known. The geographical features of North America are little less perfectly mapped than those of Europe; but large parts of the interior of South America, much of which is covered by forest, are still unsurveyed. The southern border of the North Polar Sea and the very complicated system of islands and channels along the northern margin of the American continent, between Behring Strait and Greenland, have been precisely delineated, and the boundary of the same sea along Northern Asia has also been determined. The highest northern latitude reached is about $83\frac{1}{2}°$ N., which is within 500 miles of the Pole. The nearest approach to the

South Pole has been in 78° 11′ S., but the difficulties arising from climate have till now stood in the way of any satisfactory or comprehensive survey of the land seen at some few points in the Antarctic area.

I have thus far traced in broad outlines the manner in which our present knowledge of the form and magnitude of the earth, and of the features of its surface, has been acquired in the course of many centuries by the mental and physical efforts of a long succession of remarkable men, to a few only of whom was it possible that I should make special reference. The part of my subject to which I shall next ask your attention will principally regard the operation on the inorganic constituents of the globe of the great physical forces, gravity, heat, and chemical affinity, which control and determine its movements, form, and constituents, and

underlie the distribution of land and sea and all the conditions of its surface.

The figure of the earth, and its existing features, have had their origin in a former state of the planet, during which it has been subject to the gradual changes that accompanied its cooling from a previously much higher temperature. The forces of nature which are still at work, including the most wonderful of all, life, have operated upon the globe while it thus passed through the stages which have led to what it now is; producing varied conditions of surface, from which have arisen as direct consequences, differences of climate, and corresponding variations in the forms and distribution of living creatures, vegetable and animal. Thus it is that while every part of the earth has its own characteristics, the general system of nature is one and the same everywhere; the special characters of the several regions being due to the action

of local features or conditions, which are no sooner called into existence than they in turn become secondary efficient causes of the infinitely varied phenomena that our globe presents to us. In this manner has been evolved the face of nature as we now see it—nature which, working with never-varying forces, appears to man in the present as his type of stability, whilst it is constantly leading, through ever-varying forms, from the hidden shapes of an impenetrable past to those of an unknown future.

The dominant influence of the movements and figure of the earth, which may everywhere be traced among the phenomena brought to our knowledge by the more and more complete exploration of its surface, first calls for special notice.

The diurnal and annual motions of the globe, subject to the effects of the spherical form of the earth and the direction of its axis

of rotation, determine at all parts of its surface the amount of heat and light received from the sun, and thus regulate all the conditions of existence upon it; they give rise to the varying length of days and of seasons at different places, and to a multitude of recurring phenomena which characterise or influence the animate and inanimate world. In whatever direction we turn are to be found alternations of what may be termed terrestrial work and rest; day and night, summer and winter, periodical winds extending over longer or shorter periods, seasons of rain and dry weather. The tides of the ocean, and the less apparent, though not less regular, periodical oscillations of the atmosphere, as well as the little understood variations in terrestrial magnetism, are consequences of the same general causes. All nature, indeed, is subject to them. Under their control the ocean currents flow, the

rivers rise and fall, the fields yield their harvests, the mountains are covered with snow, the florets of the daisy close and open, and the lark and nightingale pour forth their song; they regulate the migrations and hibernations of animals, the daily labours of man and beast, the hours of active life and sleep, the increase and decrease of births, disease and death.

Though many of the diurnal changes thus observed would equally follow as consequences of the sun moving round a stationary earth, yet it is not difficult to find direct evidence, which immediately appeals to the senses, of the rotation of the earth on its own axis. This is very completely supplied by what is known as Foucault's experiment, which is performed by means of a pendulum consisting of a somewhat heavy plummet attached to a long and slender string, which therefore has a long period of oscillation,

while the direction of its motion, when swung, is not liable to disturbance by torsion of the suspending string. If such a pendulum be set in motion, with suitable precautions, over a line drawn on the earth's surface, it will be found that the direction of oscillation gradually departs from that of the line over which it commenced, the divergence being caused by the gradual change of the absolute direction of the line, consequent on the revolution of the earth on its axis; a change not communicated to the pendulum, which, being only connected with the earth by means of the flexible string, continues to swing in the same absolute direction as that given to it when it was first set in motion. The apparent angular motion of the pendulum will be equal, but opposite in direction, to the angular motion of the earth on its axis multiplied by the sine of the latitude of the place where the pendulum is swung; which

at London would give an angular velocity of 1° in about five minutes. This, with a pendulum that swung through an arc of 10 feet, would produce an apparent displacement of about 2 inches in ten minutes, taking place from south, round by west, north, and east.

The movements of the atmosphere and of the currents of the ocean supply evidence of the same truth, though in a less obvious manner. The air and water at the earth's surface, when undisturbed, everywhere acquire the velocity of rotation of the globe, which is dependent on the latitude, being greatest at the equator and diminishing gradually towards the poles. The velocity thus acquired gives an apparent eastward impulse to all air or ocean currents moving from the equator towards the poles, and an apparent westward impulse to air and water moving the other way. This had long been re-

cognised as the true cause of the directions of the trade winds and monsoons. More recently the same cause has been seen to be universally operative, the direction of the south-west and north-east gales that characterise our own coasts, for instance, being due to the passage over our islands of areas of low or high pressure, which, according as they give rise to currents of air from the south towards the north, or *vice versâ*, produce winds with westerly or easterly tendencies. The revolving winds or cyclones, which are developed within the tropics in so intense a form, also carry with them a terrible testimony to the true direction of the earth's rotation on its axis from west to east.

The remarkable force inherent in the globe, known as terrestrial magnetism, which gives a determinate direction to a freely suspended magnetic needle, and is of inestim-

able value to man, has long been the subject of observation and study. The general properties of the magnetic needle were known and applied to navigation by European sailors early in the eleventh century, but much earlier by the Chinese. The fact that the direction of the needle deviates from the true north, such deviation being termed its variation or declination, was probably known before the time of Columbus; but to him is due the first record of the gradual change which takes place in passing from one place to another, he having observed in his voyage across the Atlantic that the variation which had at first been easterly at length became westerly. At an early period also, 1576, the dip of a properly balanced magnetic needle, or the inclination from the horizon at which it comes to rest, had been observed by Norman, an Englishman, as well as the fact that this angle also varies with geographical position.

The conception that the earth itself is a magnet, and gives the needle its direction, is due to Gilbert, also an Englishman, about 1600 A.D. Halley, who, in 1676, had visited St. Helena to make astronomical observations, and in 1698 undertook a special voyage to study terrestrial magnetism, first put forward a consistent theory of the variation of the compass. His final conclusions, based upon his own observations and all available data derived from other navigators, were published in 1701, when he showed that the complicated movements of the needle might be referred to the influence of four foci of magnetic force—two in the vicinity of either pole of the earth—a view which, with some qualifications, subsequent investigation has confirmed.

Halley's conclusions were derived from a comparatively small number of observations of the declination and dip alone, measure-

ments of the intensity of magnetic force not having at that time been made. This force, too, is now known to vary from place to place. The more ample collection of facts relating to both intensity and direction, since brought together from all parts of the earth, has led to somewhat modified views as to the phenomena of terrestrial magnetism. It is now established that there are two magnetic poles, one in each hemisphere, at which the needle would point vertically upwards and downwards. Their position, which is not coincident with the geographical poles, is found to have varied according to some yet unknown law. In the year 1878 the northern pole was in lat. 70° N., long. 96° W., and the southern in lat. 73½° S., long. 147½° E. Between these poles, a line that has been termed the magnetic equator, where the needle assumes a horizontal position, is found to pass round the earth, following an

unsymmetrical line which, in 1878, lay almost wholly to the north of the terrestrial equator in the hemisphere east of Greenwich, and to the south of it in the western hemisphere.

It further appears that the magnetic force is not evenly distributed on the earth, and that the points of maximum intensity do not coincide with either of the magnetic poles. In the northern hemisphere there are two foci of maximum force of unequal intensity, the more powerful lying at about lat. 52° N., long. 92° W., near the great American lakes, the weaker in lat. 65° N., long. 115° E., in Siberia. For the southern hemisphere, the available data are far less numerous, and the determination of the foci of force is less complete. It is, however, believed that here also there are two points of maximum, of nearly equal power, and not far removed from one another, one in

lat. 65° S., long. 140° E., the other in lat. 50° S., long. 120° E.

The unit by which magnetic force is measured has been assumed, adopting English standards of weight and length, to be that which would impart to a weight of one grain a velocity of one foot in one second of time. On this scale the magnetic force, where least, is found to be 6.0; the northern maxima are 14.2 and 13.3 respectively, and each of the southern 15.2.

The declination or variation of the direction of the needle from the true meridian is a consequence of these unequal forces operating upon it, the westerly or easterly tendency of the needle (as the case may be) following the geographical position of the place of observation in its relation to the several foci of force, with a general result of considerable complexity. Up to the sixtieth parallel of latitude, north or south, the

declination, whether easterly or westerly, rarely exceeds 30°; and, speaking generally, it is easterly in the Pacific and westerly in the Atlantic and Indian Oceans. Near the poles, where the dip is high, the directive force of the earth's magnetism is much reduced, and the magnetic needle becomes comparatively untrustworthy and of little use.

As what is termed the north pole of a magnetic needle or bar, attracts the south pole and repels the north pole of another needle, the magnetism of the earth at the north pole should strictly speaking be called south polar, and *vice versâ*. To avoid confusion from this cause, the north and south poles of the needle are now frequently termed the red and blue poles respectively. It may also be mentioned that magnetic declination is always measured from the true north, being described as positive when westerly, and negative when easterly.

The nature and mode of operation of magnetism, and the allied phenomena of electricity, continue to be subjects of speculation, no explanation of them having yet been proposed such as that which refers heat and light to the vibrations of an elastic medium. Our knowledge of the phenomena of terrestrial magnetism therefore still remains in the empirical stage; they are, however, held to show that the earth's magnetism is distributed through its mass, and that the magnetic force resides either wholly or mainly in the interior, and cannot be attributed to external influences, though it may be affected by them. Local variations of this force are not unfrequently found to accompany the presence of certain rocks in the subjacent strata, but how far geographical features have any influence on its general distribution is doubtful.

Observation shows that all the elements

of the earth's magnetism vary not only from place to place, but from time to time; the variations being in some cases periodical and dependent on the time of the day or the season of the year, and in others extending, with no apparent tendency to periodicity, over considerable lengths of time. The gradual alteration of the declination at London was first noticed in 1622, and the diurnal variations in 1722, in which year also the first attempt was made to measure the magnetic force. The manner in which these variations occur is still a matter of investigation, and their causes are doubtful, but the diurnal and annual changes, which are small in extent, are probably connected with changes of the temperature of the earth or its atmosphere, and may be influenced by geographical conditions. The non-periodical changes that have been recorded are very large. For instance, the

declination in England, having been 11° 15′ E. in 1580, became 24° 34′ W. in 1820, and is now 18° 30′ W. The dip has changed from 71° 50′ in 1576, to 74° 42′ in 1723, and again to about $67\frac{3}{4}$° at the present time. These variations have been attributed by some to changes going on in the condition of the interior of the earth, and by others to external influences; but they continue to be among the most obscure of physical phenomena.

Besides the variations above-mentioned there also arise other irregular disturbances of the magnetic needle, of short duration, which are sometimes spoken of as magnetic storms. They occur with a frequency which shows a tendency to periodicity, diurnal or annual, and often almost simultaneously at distant parts of the earth, with nearly identical effects, and with a marked increase in intensity with increase of latitude. They likewise exhibit a period of increase and decrease

coinciding with that observed in the sun-spot area, thus giving additional reason to connect them with modifications of the magnetic or electric condition of the earth or atmosphere arising in some manner from the action of the sun. The probable connection of these disturbances with the electrical condition of the atmosphere is indicated by their frequent occurrence simultaneously with appearances of the aurora, and with electrical earth-currents. The frequent, if not continuous, display of the aurora in the vicinity of the magnetic poles, further suggests a relation between the electrical and magnetic conditions of the earth. The true nature of all these phenomena is, however, still very imperfectly ascertained.

As the form and movements of the earth, and the distribution of the land and sea upon it, became more completely known, and as

the conceptions arising from their study were more clearly developed, inquiry was naturally extended to the nature of the terrestrial sphere, and to the forces by the action of which its surface has received its existing outlines, elevations, and depressions. The science of geology is the result; and the relation of geography to this science is what we have next to consider.

A very little observation and thought threw discredit on the ancient cosmogonies, and showed that they failed to give any satisfactory solution of the problems submitted by the advance of knowledge. If the extravagant myths of Asiatic origin, which peopled the earth millions of years ago with races of anthropomorphic demigods, and heroes descended from the sun and moon, could not bear the test of facts, neither have those traditions fared better which unveil the earth fully equipped with

all the present forms of life and specially prepared to be the dwelling-place of man, some few thousand years ago. Precise observation has now supplied satisfactory proof that the earth's surface, with all that is on it, has been evolved through countless ages, by a process of constant change. Those features that at first sight appear most permanent, yet in detail undergo perpetual modification, under the operation of forces which are inherent in the materials of which the earth is made up, or are developed by its movements, and by its loss or gain of heat. Every mountain, however lofty, is being thrown down; every rock, however hard, is being worn away; and every sea, however deep, is being filled up. The destructive agencies of nature are in never-ceasing activity: the erosive and dissolving power of water in its various forms, the disintegrating forces of heat and cold, the chemical

modification of substances, the mechanical effects produced by winds and other agencies, the operation of vegetable and animal organisms, and the arts and contrivances of man, combine in the warfare against what is.

But hand-in-hand with this destruction—nay, as a part of it—there is everywhere to be found corresponding reconstruction, for untiring nature immediately builds up again that which it has just thrown down. If continents are disappearing in one direction, they are rising into fresh existence in another. Though the ocean tears down the cliffs against which it beats, the earth takes its revenge by upheaving the ocean's bed.

When we look back, by the help of geological science, to the more remote past, through the epochs preceding our own, we find complete evidence that the globe has passed in succession through an infinitude of anterior states, by means of small modi-

fications extending over a vast period of time, but not differing in essentials from those which we see to be now going on. There are still preserved to us the remains of land and marine plants and animals — which lived, produced successive generations, and died—possessed of organs proving that they were under the influence of the heat and light of the sun; indications of seas whose waves rose before the winds, breaking down cliffs, and forming beaches of boulders and pebbles; of tides and currents spreading out banks of sand and mud, on which are left the impress of the ripple of the water, of drops of rain, and of the tracks of animals; of volcanoes pouring forth streams of lava; and all these appearances are precisely similar to those we observe at the present day as the result of forces which we see actually in operation. Every successive stage, as we recede in the past history of the

earth, teaches the same lesson. The forces which are now at work, whether in degrading the surface by the action of seas, rivers, or frosts, and in transporting its materials into the sea, or in reconstituting the land by the elevation of mountains, or by raising beds laid out in the depth of the ocean, or in volcanic eruptions, are traced as having continued in action from the earliest times.

Pushing back our inquiries, we at last reach the point where the apparent cessation, or failure of evidence, of former terrestrial conditions such as now exist, requires us to consider the relation in which our planet stands to other bodies in celestial space; and, vast though the gulf be that separates us from these, science has been able to bridge it. By means of spectroscopic analysis, it has been established that the constituent elements of the sun and other heavenly bodies are substantially the same as those of the earth.

The examination of the meteorites which have fallen on the earth from the interplanetary spaces, shows that they contain nothing foreign to the constituents of the earth. The inference seems legitimate, corroborated as it is by the manifest physical connection between the sun and the planetary bodies circulating around it, that the whole solar system is formed of the same kinds of matter, and is subject to the same general physical laws. These conclusions further support the supposition that the earth and other planets have been formed by the aggregation of matter once diffused in space around the sun; that the first consequence of this aggregation was to develop intense heat in the consolidating masses; that the heat thus generated in the terrestrial sphere was subsequently lost by radiation; and that the surface at length cooled and became a solid crust, enclosing a nucleus of much higher temperature.

The heat of the interior of the globe increases about 1° F. for every 50 or 60 feet of depth below the surface. The surface appears to have now reached a temperature which is virtually fixed, the loss of heat from radiation into surrounding space being so nearly compensated by the gain from the sun as to make the present rate of cooling practically imperceptible. As the exterior gradually cooled from its earlier condition, contractions necessarily ensued, producing change of form and dimensions; and to these, acting in combination with gravity, are, no doubt, largely due the greater irregularities of the earth's surface. The forces set up by these strains must have continued to cause movements for a vastly prolonged period, and are doubtless still in action.

But the irregularities of the surface constitute only a small part of the effects of internal heat on the earth, and mineralogy is the branch of science to which reference must

be made for a knowledge of the many simple and compound substances that have issued, under the operation of chemical forces, from the vast laboratory contained within the cooling crust of the once incandescent globe.

The solid nucleus of the earth, with the ocean and the atmosphere, as we now find them, may be regarded as the products which have resulted after the globe, by cooling, had attained a condition of practical equilibrium, and after the more active process of aggregation had ceased, and the combination of its elements, under the requirements of the laws of affinity, into the various solid, liquid, or gaseous matters found on or near the surface, had been completed; and it is not a little remarkable that two residual collections of matter, as I may term them, the air and the sea, which constitute a mere film on the solid earth's surface, should exercise so predominant an influence on terrestrial economy.

During the passage of the globe to its present state many wonderful changes must have taken place. The ocean, after its condensation from a condition of vapour into that of liquid, must have long continued in and bordered on a state of ebullition, surrounded by an atmosphere densely charged with watery vapour. Apart, however, from the movements in the solid crust of the earth caused by its gradual cooling and contraction, and the character of its inorganic constituents, its early higher temperature hardly enters directly into any of the considerations that arise in connection with its present condition; and it must probably ever remain doubtful how long and to what extent former conditions of climate which interest us most, as having occurred during the period in which the existence of life is indicated, were affected by such early higher temperature.

In the absence of any direct means of

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ascertaining the condition of the earth's interior, aid has been sought from mathematical science, by which it has been established, that the thickness of the solid outer shell of the earth must be considerable; and that if the interior is in a fluid state at all, which is very doubtful, it must be covered by a great thickness (probably not less than several hundred miles) of solid, comparatively unyielding matter; and it is argued, with apparent force, that no passage can exist by which molten matter, if there be any, could ascend from such depths to the surface. Recent speculation has consequently suggested that even volcanic phenomena may be consequences of the heat developed by intense pressures set up by the mechanical forces concerned in the movements of the cooling outer solid crust, and that they are not immediate results of the very high temperature which almost certainly still subsists at

great depths in the earth's interior. A more probable explanation would, however, seem to be that by some local or partial removal of pressure in the otherwise solid interior, a portion of intensely-heated matter is able to pass into the fluid state, and so finds a way through some fissure to the surface.

It is still an open question among geologists, whether the explosions accompanying volcanic eruptions, which are at times of most extreme violence, are due to gases generated in the formation of the ejected melted matter, or to the sudden conversion of water into vapour in cavities containing such melted matter; the latter view being supported by the facts that great volumes of steam are discharged by volcanoes during eruptions, and that the majority of active volcanoes are on islands, while those on continents are near the sea.

LECTURE III

The external features of the earth—The land, its distribution and elevation—The ocean, its depth, currents, and tides—The atmosphere—Phenomena of climate and their dependence on the conditions of the earth's surface—Winds—Rain—Ice.

THE subjects of which I last spoke related to the globe viewed as a whole, and its interior. I next pass to the consideration of its exterior, with which geography is more immediately concerned.

In the ocean we see the waters of the earth accumulated, after their condensation from a state of vapour, in pre-existing depressions of the solid surface. We find almost everywhere evidences of movements of the earth's solid crust on a very large

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scale, and of frequent changes in the distribution of land and sea. The great continents include the areas that have last risen above the sea, and clusters of islands in many cases appear to indicate the remains of former continents now disappearing.

The gradual building-up of the existing face of the earth can be traced in the succession of deposits, often of vast thickness, collected around ancient land-surfaces; and indications are everywhere to be found of subsidences and elevations, though apparently without any altogether fundamental change in the great features or relative positions of the chief areas of land and sea, which seem to have been preserved for very long periods; so that we may not improbably still see relics of the earliest forms taken by the surface soon after it attained a solid condition. Movements such as these have continued till the latest geological period, and there is

complete evidence that it was during this epoch that mountains among the highest in the world, the Himalaya and the Alps, attained their present elevations.

Mountain ranges, which are due either to pressures arising from irregular contractions of the earth's crust, or to other internal forces capable of producing an upward thrust, occur in various forms. Frequently the areas of elevation with which mountains are associated cover very large tracts, and assume the character of tablelands or plateaus, often broken up by minor mountain ranges or elevations following some determinate direction. In the larger mountain masses the valleys often appear to occupy lines of rupture or fissure determined by the tensions produced by the strains that gave rise to the elevation; and attempts have been made to explain the characteristic directions observed in the elementary portions of such

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mountain masses, on mechanical principles. In the case of areas of elevation long as compared to their width, such as the Himalaya and Tibet, the very constant combination of long ridges and valleys with shorter intervening transverse ruptures or connections, may be thus accounted for; and it has been argued that radiating ridges and valleys accompany a roughly circular area of elevation. That valleys are very frequently caused in great part, or wholly, by erosion, due to the action of surface drainage or ocean currents, especially in unconsolidated deposits, is beyond dispute; but even in such cases their origin often appears to have been in a fault or rupture of the strata through which they pass.

The great masses of land which cover a large part of the northern hemisphere are connected around the north pole, and send out diverging offshoots towards the south;

these, however, do not reach within 50 degrees of the south pole, with the exception of a small portion of South America. Generally speaking, the coasts of the continents rise steeply from great ocean depths, and very frequently high land occurs along or near their shores. In many cases the mountain-chains which bound or traverse the continents are of vast lineal extent, indicating dislocations of the solid crust of the earth which reach over very great distances and to great depths, and their frequent parallel direction suggests a probable association in the causes and time of their production. The usual distribution of volcanoes along continuous lines, extending in many cases over thousands of miles, can hardly be explained otherwise than as being consequent on the existence of ruptures in the solid crust of the earth penetrating to very great depths. The superficial extent of many of these

dislocations of the earth's crust is not less remarkable than their lineal development, and leads to similar conclusions. Such were the movements that raised the tablelands of Asia Minor, Persia, and Afghanistan, and the great desert plateau of Central Asia, and above all, the huge protuberance of Tibet, and its component gigantic mountain-chains, including the Himalaya. The high lands in both North and South America supply evidence of the same nature.

There was at first no little disinclination to accept theories which accounted for the observed facts of geology by the continued action through vast periods of time of forces now in operation. But these objections have at length disappeared, and with them the school that explained the successive steps which led to the great differences between the past and the present, by a series of catastrophes, or convulsions of nature, for

which we have no authority in actual experience.

Should any still hesitate to believe that mountains like the Himalaya or the Andes, and analogous depressions of the bed of the ocean, can have been produced by a mere secular change of the earth's temperature, I would remind them that the forces called into action by the earth are proportionate to its magnitude, and that their effects must be on a corresponding scale. It has been calculated on sound data that the contraction of the diameter of the earth, consequent on the fall of temperature from a fluid state to its present condition, has been about 190 miles. At this rate a subsidence of 5 miles, which is the approximate greatest depth of the ocean, would correspond to a fall of temperature of about 200° F. But the elevations and depressions of the earth's surface were probably produced by a

comparatively much smaller loss of heat, and were due rather to tangential strains than to direct upthrust or subsidence.

An illustration may assist in forming a proper estimate of the irregularities of the earth's surface, which, though apparently great, are insignificant when viewed in relation to its actual dimensions. This hall might contain a globe 40 feet in diameter. If this globe represented the earth it would be on a scale of one foot to about 200 miles; and one inch would be equivalent to a distance of 16⅔ miles, or 88,000 feet. On such a globe the difference between the polar and equatorial diameters would be less than one inch, and the greatest elevations in Britain would be about the thickness of a three-penny-bit. The highest mountains and the deepest seas would be shown by elevations and depressions of hardly more than one-third of an inch; and if they were distributed

as such features are on the earth, they would be visible only with difficulty, and to the unaided eyes of a casual observer would hardly interfere with the apparent perfect smoothness of the globe's surface.

The conception of the vast duration of geological time is one with which most persons are now more or less familiar. It is well to remember that great though the changes in human affairs have been since the most remote epochs of which there are records in monuments or history, nothing indicates that within this period there has occurred any appreciable modification of the main outlines of land and sea, or of the conditions of climate, or of the general characters of living creatures. The distance that separates us from those days is as nothing when compared to the remoteness of past geological ages. No numerical estimate on which reliance can be placed has yet been made of the duration

even of that portion of geological time which is nearest to us; and we can say no more than that the earth's past history, as recorded in what we now find upon it, or as inferred thence, probably extends over hundreds of thousands or millions of years.

The duration of the successive ages of the earth's past existence is measured almost wholly by reference to the fossil remains of animals and plants included in the rocks of which the crust is composed. The likeness of existing forms to those that characterise each gradually receding period constantly diminishes, and the more ancient shapes which connect the present with the several stages of the past, often, by their diffusion, supply indications of the synchronism of deposits at distant places. Light is thus thrown, though it be an imperfect one, on the former distribution of land and sea, and on the existence of antecedent communica-

tions by land and sea between parts of the earth now severed, or the converse.

It is through the facts of geography as now acquired and interpreted, that the geologist is supplied with the means of arriving at the true signification of much that occurred in past time, the traces of which survive in physical features or organic forms. He finds that the most important agencies in determining and modifying the present conditions of existence on the earth, whether as affecting inorganic nature or organic beings, are directly controlled by the actual distribution of land and sea, and the configuration of the surface; and he learns that it is by reference to these agencies that he must seek to unravel the intricacies of the past.

The study of geology, in its turn, enables the geographer to understand many things that would otherwise be unintelligible to him. He thus learns how the boundaries of sea

and land have been determined; where connections formerly existing have been severed; how islands have risen from the ocean and may be sinking below it; to what causes are due the rocky coasts and headlands, the indentations of the coasts, the formation of bays and fiords; at what time and by what means mountains have been raised up, plains laid out, valleys excavated, and the courses of rivers and positions of lakes fixed; and he is taught the constituents and qualities of the materials forming the surface of the earth, of the soil upon it, and of the minerals beneath it.

And as a better insight is obtained into the natural relations of the mountains, the plains, the valleys, rivers, lakes and seas, the conviction arises that the ever-diversified details of the face of the globe are in no sense accidents or fortuitous results, little worthy, as such, of admiration unless for

their picturesque forms or wonderful proportions; but that they are the direct, orderly, and necessary outcome of the action of forces simple in themselves, and operating in accordance with well-known and invariable physical and mechanical laws. The perception of general characteristics of structure among the various features of the earth's surface that pass under our review, is, indeed, too often overshadowed and obscured by their magnitude, by the multitude of their details, and by the variety of their forms, which at first produce impressions of hopeless confusion; but, when once the idea of subordination to common laws is duly conceived, it receives confirmation at every fresh step taken.

The area of the dry land is very greatly exceeded by that which is covered with water. The whole surface of the globe

being 197 millions of square miles, about 55 millions are land, and 142 millions water. The average height of the land above the sea-level is also very much less than the average depth of the sea-bottom below that level; so that a rearrangement of the surface would be possible, by which the whole of the land might be submerged with comparatively little disturbance of the present level of the sea, or reduction of its average depth.

The highest measured peak of the Himalaya, known as Mount Everest, which is also the highest in the world accurately determined, just rises 29,000 feet above the sea-level, but such elevations even as 15,000 feet, excepting on the Himalaya and in parts of Tibet, are confined to isolated peaks or very narrow bands along the crests of a few of the highest mountain ranges. The area above 12,000 feet is about two per cent of the whole land, and that above 6000 feet less than

nine per cent. From a careful computation recently made, it would appear that the mean height of the surface of the land above the sea-level is about 2250 feet; the continental areas having the following elevations:—Europe, 939 feet; Asia, 3073 feet; North America, 1888 feet; South America, 2078 feet; Australia, 805 feet.

The greatest depths measured in the ocean exceed 27,000 feet, and it has been estimated that the mean depth is about 12,500 feet. About five per cent of the ocean area is less than 600 feet in depth, and a somewhat smaller proportion more than 18,000 feet. About seventeen per cent is less than 3000 feet. The ocean bed generally appears to present very extensive, comparatively uniform plateaus, varied only by moderate undulations possibly to be attributed to the contractions of the earth's crust caused by its original cooling; these range in depth from

12,000 to 17,000 feet, and their general direction maintains a rough parallelism with that of the neighbouring continents. Submarine deposits derived from the land do not extend beyond 300 or 400 miles from the shores; but at great depths deposits are being formed with extreme slowness, which are probably derived from decomposed organisms, or from cosmic, volcanic, or other matter, carried down through the water.

Accepting these estimates, it will appear that the volume of land above the sea-level is about $\frac{1}{15}$th part only of the volume of the ocean. This relatively very small volume of land, and comparatively uniform great depth of the sea over very large areas, when considered in connection with the evidence that exists of the continuity of the earth's history within the range of geological time, strengthens the view, based on other considerations, that the chief masses of land as

we now find them have not greatly varied from their original position. Owing to the great depth of the sea, any upheaval of the sea-bottom sufficient to form new land, would be likely to displace a volume of water greater than that of the new land, unless it were accompanied by an equivalent subsidence and increase of depth in some other locality. Failing this, such an upheaval would be followed by an encroachment of the sea on the land, which would necessarily lose an area corresponding, at all events approximately, with the volume of water displaced, and the area thus lost might easily be greater than that gained.

With the latest additions made to our knowledge of the depth of the ocean there has also been acquired an altogether new series of facts bearing on its temperature, and its capacity for supporting life. The

variations of heat and cold, due to change of season or to day and night, which affect the surface, descend to a comparatively small depth, being greatly reduced in the first 100 fathoms, and below that depth for the most part eliminated, so that at 300 or 400 fathoms an approximately uniform temperature is met with. With increased temperature at the surface there is increased evaporation, followed by greater density, by reason of which the surface water sinks, and the higher surface temperature is partially communicated to the subjacent strata. Further, it appears that though the surface temperature of the ocean varies generally with latitude, reaching a maximum of 86°, or perhaps a few degrees higher, yet at the greatest depths, or say generally at 2000 fathoms (with an exception to be explained immediately), the water has in all latitudes a nearly constant temperature but little

above the freezing-point. This is mainly due to the flow of glacial water from the Antarctic polar area towards the warmer equatorial regions, along the sea-floor, to which it sinks by reason of its greater density. The exception referred to occurs in the case of any area which is cut off by an intervening shoal from communication with the deep glacial waters. In such cases the bottom temperature is determined by the mean winter temperature of the surface, unless the temperature of the external oceanic water at the level of the shoal be the lower of the two. Thus in the great basins of the Pacific, Indian Ocean, and Atlantic, which are of such a depth as to be in free communication with the Antarctic seas, the bottom temperature ranges from 32° F. to 36° F. In contrast with this, in the Mediterranean, which is cut off from the deep waters of the Atlantic by a shoal at a

depth of about 200 fathoms, an effectual barrier is interposed to the entrance of water of a lower temperature than about 54° F.; and no lower temperature than 55° F., which corresponds to the mean winter temperature of the surface, is found even at 2000 fathoms. In the Red Sea a similar result is observed, the bottom temperature not falling below 71° F., at a depth of about 700 fathoms.

From the mobility of water, and its high specific heat, which is almost four times that of the materials composing the land-surface, the sea-surface never acquires a very high temperature. Moreover, the evaporation which is constantly going on from the whole surface of the ocean, leads to a large quantity of the heat it receives from the sun becoming latent, and powerfully aids in preventing an accumulation of heat. These facts render the ocean one of the most important factors

of terrestrial existence; it furnishes to the atmosphere the moisture which is one of the essentials of life, and serves by the circulation of its waters and the diffusion of vapour derived from it, to equalise the temperature of the globe by moderating the extremes both of heat and cold. Hence the greater or less proximity of the sea directly and powerfully affects all conditions of climate.

The circulation of the waters of the ocean, which is set up chiefly by the action of winds on the surface, but in part by variations of temperature and of density, and by the effects of evaporation, is controlled in all its details by geographical features.

The trade-winds, which maintain over a large part of the ocean an almost constant current of air in a westward direction between the tropics, converging towards the equator, give rise to the great equatorial oceanic currents, which, impinging on the eastern

coasts[1] of the continents, are deflected to the north and south along them, and tend to establish systems of circulation in the several oceanic basins, north and south of the equator, and between the east and west coasts of the continents between which they lie. In the northern hemisphere the movement is from south to north and east along the eastern coasts, and from north to south and west along the western coasts; while in the southern the direction is the reverse, from north to south and east along the eastern coasts, and from south to north and west along the western coasts. These currents from or to the equator conform generally to the directions that would be imparted to them by the rotation of the earth, and no doubt acquire additional force

[1] To avoid ambiguity I employ the term *coast* in connection with the *land*, and *shore* in connection with the *sea*, so that an *east coast* is a *west shore*.

from this cause, particularly where the prevailing winds blow in the same direction, as they frequently do.

The most remarkable of the ocean currents is, without question, that along the east coast of North America, commonly spoken of as the Gulf-stream. It acquires great persistency from a combination of causes, which enables it to carry a very high temperature into the Arctic Circle to the north of Norway, and most powerfully to influence the climate of Western Europe, which hence offers an astonishing contrast to that of the eastern shores of the Atlantic in the same latitudes. Thus the isotherms of sea-surface temperature, from 75° F. to 40° F., on the American coast range in the summer months between latitudes 35° and 45° N.; that is, over about 10° of latitude, or 700 miles. On the coasts of Europe and Africa the same isotherms range between latitudes 20° and 70° N., or

rather beyond these limits; that is, over more than 50° of latitude, or 3500 miles. In the former case there is a change of temperature at the rate of one degree in 20 miles, in the other in 100 miles.

There are many other interesting peculiarities in the distribution of ocean temperature, to one of which I will refer. It is the occurrence of narrow tracts of relatively very cold water along certain parts of the west coasts of Africa and America, in close contiguity to areas presenting the normal temperature corresponding to the latitude. This peculiarity has been referred, with apparent reason, to the effect of the prevailing winds which, blowing from the east, drive the surface-water away from the coasts, where it is constantly replaced by the cold water which rises from below.

How greatly local conditions of surface

are able to affect the operation of the most far-reaching forces of nature is well illustrated by the tides of the ocean. The combined attraction of the sun and of the moon tends to produce a twofold tidal wave in opposite hemispheres, which, if undisturbed, would travel from east to west, or in the opposite direction to that of the earth's rotation, the times of high water succeeding one another at intervals of twelve hours twenty-four minutes, half the period of the moon's revolution round the earth, and following the apparent place of the moon, the effect of which luminary is about double that of the sun. This result is actually produced in the more open part of the ocean, chiefly in the more southern latitudes; but the distribution of the great masses of land is such that elsewhere the progress of the tidal wave in the normal direction is not possible. In the Indian Ocean and the

Northern Atlantic the principal tide is propagated from south to north; speaking generally, in our own seas the tidal wave, in approaching the west and south coasts, travels from west to east, or in a diametrically opposite direction to that of the force which generated it; while on the east coast it travels from north to south, entirely reversing the direction in which it passed up the Atlantic. In the open sea, as observed on small islands, the rise and fall of the tide is very little, amounting to one or two feet only; but the range is in some places more than 40 feet, as in the Bristol Channel, at St. Malo, on the French coast, and in the Bay of Fundy. These very high tides, as well as the strong currents which in some localities accompany the flow and ebb, are secondary results due to the gradually contracting area or diminishing depth of the portion of the ocean in which the

tidal wave is propagated, that wave originating in a movement of oscillation, not of translation.

The motion of the tidal wave is so greatly interfered with by the land, that the velocity of its transmission is eventually reduced to that of a free oscillating wave. This velocity, which depends on the depth of the water in which it is propagated, possibly averaging 400 or 500 miles per hour through the open seas, does not differ materially from that of the great seismic waves caused by the explosions which accompanied the eruption of Krakatoa in 1883, as deduced from the numerous records obtained from various parts of the earth, including the coasts of France and England, to which the disturbances reached.

The great importance, for purposes of navigation, of a knowledge of the extent and periods of the rise and fall of the tide, which

mainly depend on the distance and apparent place of the moon, has directed the attention of mathematicians to the subject, and methods have been devised by which the daily times and heights of high and low water at any port may be computed and predicted with great precision, after a comparatively short series of observations.

It has been calculated that the forces of attraction which produce the tides of the ocean are sufficient to cause some deformation of the solid globe. The whole of the movements due to these forces being in a direction opposite to the earth's rotation, give rise to friction, which leads to an extremely slow gradual reduction of the velocity of rotation. In former conditions of the earth and moon, such as there is reason to think have existed, the changes thus produced may have been very much more rapid, and their effects may have had

extremely important consequences when the globe was in a semi-fluid state. It has been suggested, in connection with speculations of this nature, that the corrugations of the cooling globe from which the existing great masses of land and the ocean beds received their original forms, may have been caused by the tide-producing forces of attraction.

Among the influences which give to the earth the characteristics that most immediately affect its fitness for occupation by man and the support of life generally, those due to the atmosphere are, without doubt, the most prominent, and, under the designation of climate, are constantly affecting us. But of all recognised branches of science, that which treats of the atmosphere—meteorology—is at the present time certainly the most backward. The reasons are not far to seek. The air is invisible, and in its

upper regions inaccessible. The changes it undergoes are difficult to observe, and, from their great complexity, difficult to grasp, while what we know of them is almost wholly confined to the immediate proximity of the earth. It is pretty certain that the most important among the causes which operate on the atmosphere are changes of temperature; but the application of mathematical reasoning to the movements of an elastic fluid such as the air, charged with watery vapour, when submitted to changes of temperature upon a rotating sphere such as the earth, presents very serious difficulties, and little has been done to grapple with them. What is known of these subjects is as yet almost exclusively empirical. Instrumental appliances are here far in advance of theories, and it is not to be disguised that great waste of labour too frequently results from an exaggerated refinement in

observation, and subsequent numerical computation, which has no real value.

The air is a highly attenuated fluid medium, beneath which the whole surface of the earth is immersed, and by which all that is on the earth is surrounded, supported, and penetrated. It is the vehicle through which warmth, moisture, and the gaseous necessaries of existence are supplied to living things. The variations of the temperature, of the pressure, and of the motion of the air, and of the quantity of vapour it contains, give rise to the great series of phenomena which are included under the general term climate. Of these variations the primary causes are the action and reaction of the mechanical and chemical changes set up by the sun's heat under the influence of the earth's motion, terrestrial position, and conditions of surface; as well as fluctuations of the sun's heat itself, though of these last we

know too little to do more than recognise their presence.

The conditions which determine at any place the greater or less degree and duration of direct exposure to solar radiation, and therefore the quantity of heat received there, are position in relation to latitude, combined with the diurnal and annual movements of the earth. The nature of the surface regulates the local accumulation of heat, by reason of the varying power of absorption or radiation possessed by different substances; while with elevation above the sea-level as the density of the air becomes less, the sensible temperature and the quantity of watery vapour are subject to corresponding change. The whole of the results thus produced, moreover, are modified by movements in the air consequent on atmospheric changes from place to place, or from time to time.

All the determining causes of variation of climate just mentioned are brought into prominently contrasted action over areas of land and water. The equable sea climates on the one hand, and on the other the extreme variations of heat and cold, of drought and flood, on the great continents, with the multitude of local results dependent on them, supply well-known illustrations of this truth.

The inequalities of the earth's surface, which are insignificant when viewed in relation to the whole globe, are of the greatest importance in relation to the atmosphere. For owing to the laws of elastic fluids, the great mass of the air and of the watery vapour it contains is concentrated very near the surface. One-fourth of the air and one-half of the vapour are found below 8000 feet from the sea-level; one-half of the air and nine-tenths of the vapour are below 19,000

feet, which hardly exceeds the average elevation of the highest ranges of the Himalaya Mountains; while three-fourths of the air and virtually the whole effective vapour lie below 30,000 feet, and therefore within the influence of the highest summits of those mountains. That portion of the atmosphere which is nearest the surface is manifestly the most likely to be acted upon by irregularities of relief, and by local variations in the power of absorbing or radiating heat or diffusing vapour. Hence it is certain that it is the movements of the lower strata of the atmosphere that chiefly affect all conditions of climate, though no doubt there are great movements in the upper regions to bring about the restoration of equilibrium, which is being constantly disturbed from below.

The principal periodical winds—such as the trade-winds, the monsoons, the land and sea breezes—are found to be essentially de-

pendent on periodical variations of atmospheric pressure, accompanying variations of temperature arising from geographical position or surface conditions. The proximate causes of the more characteristic winds of the west of Europe, and especially of our own islands, have also been well made out. These, too, are due to atmospheric disturbances producing areas of high or low pressure; the rapidity and intensity of the development of which, with the direction of their paths and their position, determine the force of the wind, the direction in which it blows, and the manner in which it veers or backs—that is, changes its direction. But how the changes of pressure originate, and what causes the transfer of the disturbed area, in a definite direction, usually from west to east, and commonly under the form of an atmospheric eddy or vortex, is still to be ascertained; though here, too, it is obvious that the distribu-

tion of the land and sea areas, and of the ocean currents, on which the temperature of the superincumbent air so immediately depends, combined with the rotatory motion of the earth, are among the principal agencies at work. The winds of our islands have commonly, more or less distinctly, the gyratory character which, as before noted, is one of the secondary results of the rotation of the earth. The precise conditions under which the great cyclones or hurricanes of the tropics are generated are still uncertain, but there is sufficient knowledge of the manner of their occurrence to show that they are disturbances set up by changes of temperature, and to enable the instructed mariner in most cases to escape their worst consequences.

With the ocean, the air performs the part of equalising temperature, and mitigating excessive local accumulations or losses of

heat; and as the ocean supplies the source of moisture, so the air distributes it, first taking it up as vapour, and then carrying it off and delivering it up, with the heat absorbed during evaporation, at distant places.

Among the most intricate problems of meteorology are those relating to the evaporation of water, the formation of vapour, its diffusion and suspension in the air, and its condensation as cloud, rain, or snow. The low specific gravity of aqueous vapour, and the constant evaporation that releases it at the earth's surface, tend to diffuse it in accordance with the mechanical laws which govern elastic fluids. But the reduction of the temperature of the air in ascending above the surface renders this diffusion impossible beyond a certain point; and observation shows that the quantity of vapour actually existing in the upper parts of the atmosphere is mainly dependent on temperature, and

amounts to not more than one-fourth part of what would be present if it were diffused freely, and simply obeyed the law of hydrostatic pressure. It follows that a height in the atmosphere is at length necessarily reached where condensation must take place and clouds or rain be formed; and that, speaking generally, the vapour in the upper strata of the air is constantly tending to a condition of unstable equilibrium, from which it may readily be once more restored to the earth in the shape of water. Thus, assuming the temperature of the air at the sea-level to be 80° F., and the vapour to be eighty per cent of what air at that temperature can hold in suspension, the free diffusion of the vapour would cause it to ascend in such quantity that condensation would take place at a height of between 3000 and 4000 feet, that being the elevation at which, the temperature of the air being about 70° F.,

the ascending vapour could no longer remain in suspension. Consequently clouds or rain would be formed at this elevation, and any further movement of the vapour upward would be arrested. This sufficiently accounts for the rarity of a perfectly cloudless sky, which indeed can hardly exist, excepting where such a movement of the air is going on as will carry off the aqueous vapour, as fast as it is formed by evaporation, to a region where the temperature is high enough to prevent its condensation.

The great activity of the air in discharging the function of equalising temperature and distributing moisture over the earth is remarkable. Reckoning the mean temperature of the air at the earth's surface at 58° F., the mean maximum tension of vapour possible at the surface would be less than half an inch of mercury, which would not represent a true hydrostatic pressure of

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water vapour of more than one-fourth part of that amount, or little over one-tenth of an inch of mercury. If, therefore, the whole quantity of moisture in the air at any moment were condensed so as to leave it absolutely dry, the resulting stratum of water, if distributed evenly over the whole earth, could hardly be more than one inch in depth. Yet it is estimated (though perhaps on insufficient data) that the mean rainfall over the whole globe is not less than 60 inches in the year, and falls of ten times this amount are known to occur in some localities. Observations of the velocity of the wind at marine stations show that these results are due to the almost unceasing passage of air highly charged with vapour over the regions where, and during the time in which, rain thus falls, and to the unceasing renewal of the supply of moisture brought from a distance; and thus the relatively very large

sea-area has an important effect in maintaining the supply of the rain that falls on the land.

The immediate dependence of rainfall on local geographical features is well known. The presence of mountains forming a barrier in the path of the vapour-bearing winds may determine on the one side a climate of perpetual cloud and rain, and on the other vast tracts of desert. Where no mountains exist to cause condensation, such winds may pass on, leaving deserts behind them, and carry their waters to fertilise more fortunate lands beyond.

Instances of the fall of rain in excessive quantities on the windward faces of mountains exposed to winds blowing from over the sea, with relative drought to leeward, may be found in every part of the globe. In the British Isles may be mentioned the excessive rain on the hills of Cumberland exposed to the south-west winds that blow directly up

the Irish Sea and St. George's Channel. In Ireland the same facts are to be observed on every one of the clusters of hills that stand up above the otherwise low flat surface. The contrast between the fall of 73 inches at Bergen, on the coast of Norway, directly exposed to the south-west, and its reduction to one-third of that quantity at Christiania, and to one-fifth at Upsala on the continental side of the Scandinavian Peninsula, is most striking. The rainy and well-wooded eastern slopes of the Andes may be contrasted with the barren western flanks of the same chain, where it hardly ever rains; and the rainless district of Chili on a west coast, south of the equator, coinciding with the region of the south-east trades, where there is a constant current of air from the coast seaward, displays almost the exact reverse of what is observed north of the equator on parts of the west coasts of Europe and Asia, where the rain

falls in torrents during the seasons when the south-west winds blow inland from over the ocean.

The action of the periodical winds or monsoons in bringing with them the seasons of rain in the tropical and semi-tropical regions of the earth, is of the greatest practical moment. The water-supply and the production of the ordinary food-crops are often wholly dependent on such rains; and the light thrown by science on the controlling causes of their failure or abundance may enable us to foresee the possible occurrence of drought, so as to guard against its worst consequences.

A few words will indicate approximately the magnitude of the forces which are called into silent and comparatively unobserved operation in the atmosphere, in the production, dissemination, and recondensation of aqueous vapour. It has, as I noticed, been estimated

that on the average 5 feet of water falls annually as rain over the whole earth. Supposing that condensation takes place at an average height of 3000 feet above the surface, the forces of evaporation and diffusion must exert a power capable of lifting 5 feet of water over the whole surface of the globe, 3000 feet during the year. This, not reckoning the force required for the transport of the vapour in a horizontal direction, would be equivalent to lifting 3,250,000 millions of pounds of water 3000 feet in every minute, which would require nearly 300,000 million horse-power constantly in operation. It may assist in the apprehension of these numbers to mention that the engines of the largest ironclad do not exceed 12,000 horse-power. Even if the quantity of rain were, in fact, not more than one-tenth part of that above supposed, which is not at all probable, the forces thus exerted would still be on a scale

of magnitude which can hardly be brought within the reach of ordinary conceptions. Of these huge energies a very small part is transferred to the waters that run back through rivers to the sea, and of this a still smaller fraction is utilised by man in his water-mills; the remainder is dissipated in celestial space.

A well-known consequence of the physical properties of the air is the gradual reduction of temperature in the higher parts of the atmosphere, as observed in ascending mountains. This, amounting to 1° for about 300 feet of elevation, gradually produces a change of conditions similar to that caused by passing from the equator towards the poles; and at the greatest elevations an arctic climate is established even under a tropical sun.

Among the sublimest sights furnished by nature are the great ranges of mountains which traverse or approach the tropics;

rising into the regions of perpetual snow, they discharge important functions in the economy of the globe. By the intrusion of the solid terrestrial surface into the upper part of the atmosphere, the low temperature there, which otherwise could have produced no effect on the earth, is brought into active operation; great rivers spring from the melting fields of snow and ice that crown the mountain summits, and, swollen by the copious condensation of rain on their slopes, flow down to the plains below, which are fertilised by their perennial waters.

Ice, whether in the shape of glaciers excavating their mountain beds, or as the floating fragments of glaciers which, forming icebergs, tear up the floor of the ocean, or whether when expanding in the fissures of rocks it rends them asunder, is one of the most energetic of destructive agents. The

recurrence in the earth's past history of glacial epochs alternating with epochs of greater heat, of which geology supplies evidence, is of much interest, and has given rise to much speculation. Alterations of the distribution of land and sea, and the elevation of mountain-chains, though capable of producing great changes of climate locally, seem insufficient to account for the observed phenomena extending as they do over large portions of the globe. A more probable cause is to be found in the variations which in the lapse of time take place in the ellipticity of the earth's orbit, combined with changes of the position of the axis due to precession. At a period of maximum ellipticity, the quantities of heat received by the earth, at its least and greatest distances from the sun respectively, must be increased and diminished accordingly; and should it happen that at such a time the change in the direction of the earth's axis

caused by precession, brought either hemisphere to face the sun fully when nearest to the earth, very considerable effects on the summer and winter temperatures of the two hemispheres must be produced, without affecting the mean temperature of the globe; in the more directly exposed hemisphere the summer would be shorter and hotter, and the winter longer and colder, while in the other hemisphere there would be a milder and shorter winter, and a longer but colder summer. Again, it is far from impossible that actual changes in the sun's heating power may have had an important influence on the temperature and climate of the earth, and may have contributed to the results in question. But in the present state of our knowledge any opinion on this subject must be regarded as little more than speculative. Displacements of the earth's axis of rotation have also been suggested as a means

of accounting for some of the great local changes of temperature indicated by geology; but the evidences of such displacements hardly amount to more than arguments based on mathematical reasoning, which show that they are not incompatible with established facts.

LECTURE IV

Phenomena of Life—Doctrine of evolution under varying terrestrial conditions—Distribution of vegetable and animal life—The place of man—His dependence, physical and intellectual, on Geographical influences—Geography in relation to the practical affairs of life, and the prosecution of other studies—Conclusion.

IN my previous lectures I have endeavoured to show how, under the action of inherent or external forces, the globe has been moulded to its present form, and has received the existing configuration of its surface; and how, from the action of similar forces on the atmosphere, have resulted all those local conditions and characteristics of climate which have fitted it for the support of life. We thus find ourselves at the mysterious line

which separates inorganic from organic matter.

Of the origin of life, either when or how it began, we know nothing; all that can be said is that the earlier conditions of the earth were altogether incompatible with life as we know it. For thousands of years as the globe cooled down, its surface must have been deluged with boiling water; and until a temperature had been established not very greatly exceeding the present, none of the forms of life found in the oldest fossiliferous rocks could have come into existence.

The sharp distinction between animal and vegetable formerly made is quite broken down; the bond that subsists between things with and things without life is testified by the identity of the elements of which they are all composed; and the only possible conclusion is that life is in its nature analogous to other properties of matter, and that it is in fact in

some unknown way a necessary attribute or consequence of matter in certain conditions, though we are wholly ignorant what the connection is and how it is maintained.

Life is restricted to a very thin stratum on the surface, quite insignificant in comparison to the total magnitude of the earth. The possibilities of life, its preservation, and the propagation of living things, are further seen to be everywhere directly influenced by external conditions such as the presence of a medium necessary to existence, be it air or water; heat, moisture, and light; the periodical recurrence of the seasons and of days and nights; depth in the ocean; the character of the surface of the land, whether it be covered by vegetation or otherwise; the nature of the soil; the presence of other living creatures; and many others.

Discarding speculation as to its origin, of which we have hitherto been unable to obtain

evidence, our scientific theories of life are based on the study of the structure and distribution of existing plants and animals, and of the corresponding facts established in relation to past time by the aid of geology. We thence learn that all forms of life may be arranged in groups, which by their structural affinities are suggestive of natural relationships, and exhibit gradations of successively closer degrees of proximity. Thus we find at the outset the great primary divisions or *Kingdoms*, of Animals and Vegetables, having respectively certain common characteristics of organisation. Subordinate to these, various minor divisions or *Sub-kingdoms* have been established in like manner, such as Vertebrata or Mollusca among animals, and Monocotyledons or Dicotyledons among plants; and further, in succession, Classes such as Mammals or Birds, then Families, and Genera, until we at length reach associa-

tions of individuals known to be related by descent from a common ancestor, to which the collective name of Species is applied. Viewing these in a reverse order, a series of allied Species will constitute a Genus, of allied Genera a Family, and so forth. We also see that the assemblages of living creatures found in countries adjoining and easily accessible to one another, and alike in climate, are similar; that as distances increase, and communication becomes less easy, and climates differ, a corresponding dissimilarity appears; and that great distance and complete separation are generally accompanied by great changes of forms. Distance in geological time has the same effect as distance in space; the farther we go back into the past, the more different were the forms of life from what they now are. The abundance of forms of life (distinguished from number of individuals) is also found to vary greatly in different areas, and

to be related to the existence, within or near the areas, of localities offering considerable variations of the conditions that chiefly affect life; to the accessibility of these areas to immigration from without; and to the compatibility of the local climate and conditions with such immigration.

Thus is presented the great problem of Life in its infinite variety of forms, past and present; consisting of groups of animals and vegetables, manifestly connected among themselves by certain common features of organisation, and distributed over the globe in a manner no less plainly indicating a common origin. The question arises whether or not these phenomena can be accounted for without having recourse to any other means than that which direct observation shows to be alone capable of producing living creatures, namely, propagation by generation through descent from

parent to offspring. The answer has been given in the affirmative by Darwin, to whom we are indebted for a theory of life analogous in its breadth and the genius it displays to the great conceptions of Newton. Darwin has shown how propagation by descent, which maintains the essential characters of hereditary likeness, accompanied by certain small variations in the offspring, would be followed, through the influence of external conditions, by the necessary preservation of some of the varieties to the exclusion of others, and how this would account for many of the facts observed, while inconsistent with none. In the preservation or destruction of forms by reason of favourable or unfavourable external conditions (to which he applies the term Natural Selection), he has obtained a solution of the mystery of the structural affinities of the various forms of vegetable and animal life. He has thus also explained

how it is that uniformity of conditions and facilities for diffusion over any area are found in connection with similarity of forms of life throughout the area, and how any break of continuity of conditions, or surface, or time, involves differences in forms of life. Great tracts like Northern Europe and Asia, extending along the same parallels of latitude, not broken up by high mountains, are biologically one. Great mountain ranges like the Himalaya, great deserts and wide oceans, constitute impassable barriers. Isolated lands, like Madagascar, Australia, and oceanic islands, are dissociated in their life-forms from the great continents, in different degrees which seem to connote the geological date at which they were severed from the large land areas; and it is significant that this dissociation in island forms is always accompanied by corresponding depth in the intervening ocean. Analogous results are found in the seas.

Again, accompanying the gradations of climate that occur on lofty mountains rising from tropical plains, corresponding changes in the forms of life are found at different elevations; on chains ranging through many degrees of latitude, like the Andes, there is greater variety of life, corresponding to greater variety of climate, than on those nearly following the same parallel of latitude, like the Himalaya. Extensive land areas appear requisite for the evolution and support of the larger forms of terrestrial life, while restricted areas are characterised by smaller forms and fewer of them.

The laws that govern the diffusion and limitation of vegetable and animal life are similar; but though some of the great natural provinces marked out on the earth's surface by characteristic assemblages of plants and animals are respectively more or less conterminous, no exact correlation has

been established between them, the cause of which may no doubt be found in want of complete conformity in the operation of the laws of distribution on the two great divisions of living creatures.

Many apparent difficulties in accounting for the existing facts of distribution are solved by a consideration of the great changes that have taken place in the outlines of land and sea in past time. The data necessary for any complete solution of all the questions that arise are wanting, in consequence of our still very limited knowledge of the geology of many parts of the earth, and ignorance of what extinct forms of life may be lost or concealed beneath its surface. But every fresh fact discovered seems to strengthen the evidence of the truth of Darwin's theory of evolution as to its essential factors.

The phenomena of which I have been speaking indicate, moreover, much more than

a simple conformity of life to the conditions under which it subsists ; for the conditions, in fact, have positively determined the forms that have been preserved, so that the directing forces which have been efficient in developing life as it exists from what went before, are those same successive external conditions, including the forms of both land and sea and the character of the climate, which have already been shown to arise from the gradual modification of the material fabric of the globe as it slowly attained to its present state. These conditions, through the preservation of those forms best suited to survive and flourish under them, have controlled the course of the production of living creatures by propagation through successive generations, leading from the past to the present. In each succeeding epoch, and in each separate locality, the forms thus preserved and transmitted to the future were determined by

the general conditions of surface at such time and place; and the aggregate of successive sets of conditions over the whole earth's surface has determined the entire series of forms which have existed in the past, and have survived till now.

Perfectly unbiassed evidence of the truth of this conclusion is found in the tendency shown before Darwin's great generalisations, to give weight to geographical distribution in systematic classification. And though it be true that classification should rest wholly on morphological considerations, yet the structural likeness among forms geographically associated is often so complete, while so many links in the chain of evolution have been lost for ever, or still have to be found, that, on the one hand, distribution may without objection furnish collateral aid in the details of systematic arrangement, and, on the other, structural resemblances among forms now

dissociated may serve to suggest changes of former geographical conditions of which no other evidence remains.

These conceptions of the dependence of animal and vegetable forms on the condition of the earth in its successive stages lead to views of the significance of type (*i.e.* the general system of structure that characterises the various groups of organised beings) very different from those formerly held. In the light of evolution, type indicates nothing more than the direction given to the actual development of forms of life by the surface conditions of the earth. Beyond this there is no indication of any inherent or prearranged disposition towards a development of life deviating in any particular direction from that which follows the hereditary principle. It rather appears that the existing face of nature is the result of a succession of incidents, unimportant in themselves, which by some

very slight alteration of local circumstances might have been turned in a different direction. For instance, a difference in the constitution or sequence of the substrata at some locality might have determined the elevation of mountains where a hollow filled by the sea was actually formed, or the converse, whereby the whole of the climatal and other conditions of a particular area would have been changed, and an entirely different impulse there given to the development of life.

But further, all that we see or know to have existed upon the earth has been controlled to its most minute details by the original constitution of the matter which was drawn together to form our planet. The character of all inorganic substances, as of all living creatures, is only consistent with the actual constitution and proportions of the various substances of which the earth is com-

posed. Other proportions than those present in the constituents of the atmosphere would have required an entirely different organisation in all air-breathing animals, and probably in all plants. Any considerable difference in the quantity of water either in the sea or distributed as vapour, must have involved corresponding changes in the constitution of living creatures. Without oxygen, hydrogen, nitrogen, and carbon, what we term life would have been impossible. But such speculations need not be extended.

The doctrine of the dependence of life on external conditions includes life itself as an important concurrent agency in the general results observed. Thus, in order to supply the food and other requirements of animals, the presence of vegetables or other animals is necessary. To some animals, as well as to some plants, the shelter of forests or particular forms of vegetation is essential. Parasites

need for their sustenance living plants and animals. The fertilisation and hence the propagation of plants is very commonly due to insects; and the infrequency of certain forms of insect-life in some of the islands of the Pacific, is held by Wallace to be the true cause of a corresponding infrequency of flowering plants.

So, too, the reaction of organic matter on inorganic may be seen over the entire globe. The building up of coral-reefs; the laying out of many calcareous and siliceous deposits over the bed of the ocean; the action of vegetable life on the constituents of the atmosphere; the effects produced by vegetation in modifying the absorption and radiation of heat by the soil, and the conditions of moisture,—show how vital forces actively affect the condition of the earth.

As life, viewed in one aspect, performs the

function of sustaining life, so in another it works for its destruction. Among the latest results of science may be noticed those that trace, with certainty in many cases, and with much probability in others, particular forms of disease among insects and plants, as well as among the higher animals, to parasitical organisms; and show how these withdraw the necessary elements of healthy existence, and may at length lead to the total dissolution of the creature in which they are produced. Thus, like the forces that act on inorganic substances, life also follows the same incessant round of construction and destruction; it elaborates from the constituents of the earth and atmosphere new combinations of matter, soon to be again dissolved, thus restoring the elements on which its own renewal depends.

The divisions of the earth's surface now generally adopted by naturalists as best repre-

senting the regions characterised by groups of animals and plants with well-marked common features, will be found to be arranged round the globe, so as to conform roughly with the zones of equal temperature.

Thus the vegetation has been divided into three great provinces:—the *Northern*, occupying the northern hemisphere, in both the Old and New Worlds, as far as the tropic; the *Tropical*, embracing the regions between the tropics, exclusive of Australia; and the *Southern*, including Australia and the adjacent islands, and the temperate zones of South Africa and South America.

Zoologists have adopted somewhat different divisions, but they are, in their main characteristics, analogous to those just described. The groups usually accepted in our own country are as follows:—The *Palæarctic*, including Europe, with temperate Asia, and Africa north of the Sahara desert,

and the *Nearctic*, extending over the corresponding parts of America; the *Ethiopian*, including Africa south of the Sahara and South Arabia, and the *Indian*, embracing India south of the Himalaya, South China, the Malay peninsula and islands; the *Neotropical*, extending from South Mexico, over South America and the West Indian Islands; and the *Australian*, including the continent of Australia and the neighbouring islands of the Pacific.

The opinion that life originated in the polar regions, where the gradually cooling globe must first have reached a temperature in which it became possible, was, I believe, first expressed by Buffon. Speculations on such subjects must obviously be received with much reserve, but there are indications considered valid by competent authorities, that it was around the north polar area that both vegetable and animal life were first developed,

and thence disseminated over the rest of the earth; and it seems to be an accepted opinion that even if the northern hemisphere be not the area in which both plants and animals were originated, and from which they have been diffused, it has at all events played a most important part in the evolution and distribution of new types.

Within this area have been found representatives of all the principal known fossiliferous systems, containing the remains of plants and animals closely resembling the present inhabitants of far lower latitudes, and even of tropical climates. Thus in lat. 82° N. are to be seen Silurian rocks containing undoubted reef-building corals, such as now exist under the equator in water having a temperature from 70° to 85° F. In many localities within the arctic circle, in some cases reaching within 10° of the pole, have been found accumulations of the remains of de-

ciduous trees, in all respects resembling those now seen in the warmer temperate regions.

It is also inferred from the manner in which existing forms are distributed that there has been in past geological time a general migration from north to south, interrupted from time to time and in various localities by secular changes of temperature and climate, or by alterations in the boundaries of land and sea, or the elevation of mountain ranges, and even occasionally reversed in direction.

The glacial epoch of the Tertiary period, during the later portions of which great movements of the earth's crust occurred without material changes in the relative positions of the chief masses of land, appears to be the event which has mainly determined the local characteristics of present forms of vegetable life, the pre-existing flora of large parts of the northern hemisphere having then

been either wholly or partially destroyed by cold, or driven southwards into what are now regions of tropical heat. Through the effects of the change of climate that then occurred has also been explained the presence of plants of the Arctic regions on many of the highest mountains in distant parts of the world and even in the Antarctic area, to which their migration under existing terrestrial conditions would be impossible. Such plants might have travelled southward, as the cold in the north became more intense, along mountain ranges extending for great distances from north to south, such as the Rocky Mountains and Andes, or possibly other chains no longer existing. With the return of the warmer climate the relics of the Arctic vegetation might be left in isolated areas, where a suitable temperature continued, as on the highest mountains and in the Antarctic regions. Such changes occurring at any

time in the earth's history would have caused the then existing flora to be broken up and to be subjected to great modifications by successive migrations in alternating or varying directions; introducing tropical forms into what had been temperate areas and *vice versâ.*

Changes of temperature such as those of the glacial epoch, would appear to have had hardly less influence in modifying the fauna of large parts of the earth, though in consequence of the relatively far greater inability of plants to escape from conditions of climate incompatible with their organisation, the present distribution of animals and the special characters of a local fauna may be more largely due on the one hand to former connections between adjacent areas which may no longer exist, and on the other to prolonged isolation or separation.

But while these are the influences which

have determined the production and distribution of the existing types or forms of life, it is the actual conditions of the regions they inhabit that control their preservation, and their greater or less abundance, and indeed all that may be termed their relations with the earth and one another.

The amount and extent of the variations of the heat and moisture of the air and of the rainfall, the force and direction of the prevailing winds, and the nature of the surface, are among the essential conditions that determine the possibility of life; and it is therefore to geographical features and position that we must look for the dominant influences under which life in its various forms exists on the earth.

Under these influences the vegetation which clothes the land and fits it for the support of animal life, in turn appears as the almost impenetrable forest and undergrowths

of the tropics; as the more open woods and glades of the temperate zone; as the herbage of the prairies, meadows, and plains that invite the herdsman, the shepherd, or the plough; dwindles here to the dwarfed bushes scattered over a desert; is seen there as a few alpine plants seeking shelter among crevices in the rocks; and finally, before disappearing in the regions of eternal frost, is reduced to some patches of lichen.

On the slopes of the great mountain ranges that rise from tropical heat to the regions of everlasting snow, the traveller as he ascends may find within the compass of a few days a compendium of the climate, and consequently of the vegetation of the entire globe.

Nowhere can such a display be better or more easily obtained than upon the Himalaya Mountains. The transition is abrupt from the well-cultivated plain of Northern India,

with its fields of rice and millets, or golden-flowering mustard, to the umbrageous forests lying at the foot of the outer ranges, almost wholly composed of trees of tropical forms, but among which a few oaks and an elm are found, and which, with a tangled growth of undershrubs and creepers, and adorned with epiphytal plants in profusion, give cover to the elephant, rhinoceros, and tiger, and afford shelter to the peacock and a multitude of other gaily-coloured birds. The glens are choked with gigantic grasses and feathering bamboos. Great forests cover the outer slopes of the chain, scandent palms spreading over the lofty trees, whose stems are splendidly furnished with the dark green foliage of climbing aroids; the ground beneath them is concealed under a rich growth of tree and other ferns, orchids and scitamineæ, or broad-leaved plantains. With gradually increasing elevation and falling temperature, the char-

acter of the vegetation changes. More open woods of evergreen trees, typical of warm temperate climates, succeed, including rhododendrons, oaks, and laurels. Lofty pines cover the vast mountain sides through many thousand feet of altitude in unbroken uniformity. Still ascending, forests of deciduous trees of surpassing size and beauty appear, crowning the hilltops and fringing the courses of the rivers, intermingled with many flowering shrubs and an abundant display of herbaceous plants, of which at the greater elevations the forms are for the most part allied to or identical with those of Europe. The arboreous vegetation, the last members of which are commonly birches, pines, and junipers, ends at about 12,000 or 13,000 feet above the sea-level, the shrubby growths ascending a thousand feet higher. The alpine region is thus attained, where, under the influence of the frequent showers that

fall on the mountain slopes exposed to the south, the open pastures are adorned, during their short summer, with flowers of every hue and in the greatest profusion and luxuriance, including well-known European forms, such as gentian, primula, anemone, ranunculus, and many others.

With increased elevation, and as the ranges are less directly exposed to rain-bearing winds from the south, the climate becomes colder and drier, the vegetation more scanty, the forms fewer; and on reaching the border of Tibet at an elevation of 14,000 or 15,000 feet, where the atmospheric conditions are wholly changed, the aspect of the country is that of a desert, treeless and bare; as a rule, and excepting in the rare neighbourhood of water, not one-twentieth of the surface is clothed with vegetation, and such bushes as there are seldom rise to a greater height than one or

two feet. On the Tibetan plateau, where the precipitation of moisture is confined to a few showers in the summer, and scanty falls of snow in the winter, the surface drainage frequently collects in salt lakes; and at these great elevations many salt plants are found, with species of wormwood, and assemblages of truly seashore plants, precisely such as may be seen together at any time on the coasts of the British Isles. The general character of the scanty vegetation is European, but combined with many Siberian forms, and several species are identical with those of the Arctic regions. With the semi-arctic climate of Tibet, corresponding northern forms of animal life also appear, such as the marmot, lagomys, and other burrowing animals, the ounce and the lynx. The great open half-desert plateaux supply a suitable home for peculiar antelopes and troops of wild asses, and the more inaccessible

mountain tracts afford shelter for several species of wild sheep.

Analogous to the modifications in the character of the vegetation observed in ascending to great elevations, are those which accompany changes of geographical position and conditions in crossing a great continent such as North America.

The portion of the North American continent lying along the 40th degree of latitude, and extending from the Atlantic to the 95th meridian west from Greenwich, over a distance of about 1200 miles, may be described as a great plain gradually rising from the sea-level to an elevation of about 1000 feet along its western border. From it rises, at about 200 or 300 miles from the coast, the Apalachian range of mountains, few of the summits of which exceed 5000 feet in elevation, and but a small portion reaches even 3000 feet. Along the eastern margin

of this region there is a considerable rainfall, from 40 to 50 inches fairly distributed through the year, which is gradually reduced to about 35 inches on reaching the 95th meridian west. The Apalachian Mountains appear to have no important influence on the total annual rainfall, and the whole tract, before civilised man began to intrude on it, was covered with a vast primeval forest, probably the largest and richest in the temperate zones.

To the westward of the 95th meridian the rainfall rapidly diminishes, while the elevation of the plain increases, and accompanying this change the forest region ceases and that of the prairies begins. This extends over a distance of about 600 miles to the foot of the Rocky Mountains, where, at an elevation of between 5000 and 6000 feet, the rainfall is reduced to little over 15 inches. As the western margin of the great forest region is approached it is invaded by open grassy belts,

which soon become dominant, and there is an abrupt and surprising passage into the prairies, which extend their bright green rolling undulations to an apparently boundless horizon, with nowhere a tree to be seen, excepting along the rivers whose distant courses are marked out by scattered lines of poplars.

The Rocky Mountains, which rise abruptly from the prairie, and whose highest summits, which reach about 14,400 feet above the sea-level, immediately overlook the eastern plains, constitute in truth the eastern escarpment of a great irregular tableland extending for a distance of 800 miles as far as the mountains of California, which, in like manner, there form its western flank. The average elevation of this plateau, the surface of which is much broken up, is probably not less than 6000 feet; considerable areas rise to upwards of 8000 feet, and detached portions, chiefly towards the eastern escarpment, reach from

10,000 to 12,000 feet. The rainfall over parts of this region does not amount to 5 inches in the year.

The eastern slopes of the Rocky Mountains are covered with forest, but of a scanty character, except in sheltered valleys and on the higher ridges, where condensation is most considerable, and the vegetation—arboreous, shrubby, and herbaceous—is more vigorous. The forest is mainly composed of pines, and almost the only deciduous tree is a gregarious aspen, which forms nearly impassable thickets.

A few miles beyond this more favoured region begins the great desert basin, of which the country round the Great Salt Lake City is typical, and on which the scanty surface drainage collects in salt lakes and pools. There is an almost complete absence of grassy sward, and the surface over very large areas is exclusively clothed with the shrubby sage-bush, artemisia, and various saline plants,

chiefly chenopods, stretching as far as the eye can reach, in low detached clumps; the prevailing colour of these, a dull gray or olive-green, conveys no unsuitable impression of the dreary and inhospitable character of the country, which in its general aspect resembles in a marvellous degree those parts of the Tibetan plateau which are in like manner cut off from rain by the lofty ranges of the Himalaya.

The western border of this desert region is formed by the Sierra Nevada range of mountains, rising to elevations from 11,000 to 14,000 feet, its slopes descending to the Pacific, distant about 150 miles. On these abundant rain once more prevails, and the treeless waste is replaced by a forest tract of incomparable grandeur. But the essential characters of the vegetation differ in a most conspicuous manner from those of the Atlantic forests. Large numbers of the most

abundant trees of the east are absent, and the forests of the Pacific are chiefly made up of conifers, among which must be specially noticed the far-famed gigantic sequoia found in the Yosemite Valley, known as Wellingtonia in English gardens. The age of the largest of these, which rise to the height of over 300 feet, with a girth of more than 100 feet at 6 feet above the ground, has been estimated to exceed 3000 years; their parentage probably goes back to the glacial epoch, or even to a more remote date, but the race is almost inevitably doomed to destruction by the advent of man. North of lat. 35°, under the influence of the equable coast temperature, the moist climate, and the heavy rainfall which rises to 80 inches in lat. 40°, similar forests of great magnificence and beauty clothe the mountains skirting the Pacific.

The distribution of life has been greatly disturbed by the occupation of large parts of

the earth's surface by man, from which have followed the destruction of much of the primeval vegetation and animal life, and the introduction of foreign or modified forms by means of artificial methods of propagation and culture. But the various plants which man has thus substituted to supply his food and his clothing; the cereals, sugar-cane, grape-vine, tea, coffee, cotton, flax, hemp, and so forth, have their special requirements of climate and soil, and the areas within which they can be profitably raised are well defined geographically; and all such artificial operations are subject to similar limitations.

The animal kingdom is as directly under the influence of the physical conditions of the earth's surface as the vegetable, and is no less certainly ruled by them. Every animal must yield to the necessities imposed upon it, through its dependence for food on the vegetable products of the earth, or on other

animals fed on those products, and for the protection which vegetable life affords against foes and the pressure of climate. The terrestrial conditions which permit the growth of forest, determine the presence of those animals for the requirements of whose organisation tree vegetation is essential. Where open plains cease, the wild horse or ass, the camel and antelope, disappear. The most inaccessible crags on lofty mountains are the selected home of wild sheep and goats. Certain genera of mollusca can exist only within reach of the action of the waves of the sea. Other creatures are found exclusively in the lowest depths of the ocean. Such instances might be extended indefinitely.

In what I have thus far said I have not distinguished man from the rest of the animate world, in which he holds the most conspicuous place. The progress of knowledge has re-

moved all reasonable doubt as to his relation with other living creatures. It is now established that man existed on the earth at a period vastly anterior to any of which we have records in history or tradition. He was the contemporary of many extinct mammalia at a time when the outlines of land and sea, and the conditions of climate over large parts of the earth, were wholly different from what they now are; and modern research has done much to show how our race has been advancing towards its present condition during a series of ages, for the extent of which ordinary conceptions of time afford no suitable measure. The ancient monuments of Egypt, which take us back perhaps 7000 years from the present time, indicate that when they were erected the neighbouring countries were in a condition of civilisation not very greatly different from that which existed when they fell under the dominion of the Romans or

Mahommedans hardly 1500 years ago; and the progress of the population towards that condition can hardly be accounted for otherwise than by prolonged gradual transformations, going back to times so far distant as to require a geological rather than an historical standard of reckoning. The facts thus brought to light have, in recent years, given a different direction to opinion as to the manner in which the great groups of mankind have become distributed over the areas where they are now found; and difficulties once considered insuperable become soluble when regarded in connection with the now ascertained extreme antiquity of the human race, and those great alterations of the outlines of land and sea which are shown to have been going on up to the very latest geological periods.

The better knowledge now acquired of the want of stability of forms of human speech

has also had an important bearing on these same subjects. For the evidence of the modifications which the chief spoken languages have undergone during the historic period shows that there is probably no country in which the tongue in use a thousand years ago would be now intelligible; and in still more remote ages, in the absence of written language, the tendency to the production of diverging forms of speech must have been much greater. This leads to the conclusion that even a radical diversity of language need not imply difference of race, an inference fully supported by what is known of the languages of existing savage tribes.

There is still considerable disagreement among ethnologists as to the groups in which the human race should be classed, and the explanation of apparent affinities in various parts of the earth. Everywhere, however, a distribution is to be found corresponding

in its chief features with that of other forms of life, following mainly the geographical distribution of land and sea, and limited by local conditions of climate. The largest area is occupied by the Mongolian race, which extends over the greater part of Northern and Eastern Asia, and is supposed to have spread over the islands of the Pacific, and the entire continent of America. The European races, commonly called Caucasian, occupy Europe, the northern parts of Africa, and South-western Asia. The Negro races are peculiar to Africa south of the great desert, though with an apparently exceptional extension to some of the islands in the Indian Archipelago. The Australian continent is peopled by a distinct race, of which traces are thought to be found in Southern India, Arabia, and possibly Egypt. In our ignorance of the time and manner of the development of these different races no thoroughly satisfactory

explanations have been given of their mutual relations, or of the peculiarities of their distribution, some of which have been attributed to the changes of the boundaries of land and sea known to have occurred during, or subsequent to, the geological period in which the earliest traces of man are found.

What were the steps through which primeval man passed in acquiring his present place in the advancing front of living creatures will probably never be more than matter for speculation; but there is no room to doubt that for this position he is indebted not to any special efforts of his own directed to such an end, but to the wonderful compelling forces of nature which, acting on some inherited capacity, have lifted him entirely without his knowledge, and almost without his participation, far above the animals of whom he is still one, though the only one able to see or consider what he is.

For the social habits essential to his progress, which he possessed even in his most primitive state, man is without question dependent on his quadrumanous ancestors, as he is for his form and other physical peculiarities. In his advance to civilisation he must have been insensibly forced, by the pressure of external circumstances, from his primeval condition, in which he derived sustenance from fruits or roots, and wild animals, to pastoral and agricultural occupations. The requirements of a population gradually increasing in numbers could only be met by a supply of food more regular and more abundant than could be provided by the spontaneous produce of the earth or by the chase. But the possibility of the change from the hunter to the shepherd or herdsman rested on the antecedent existence of animals suited to supply man with food, having gregarious habits, and fitted for domestication, such as

sheep, goats, and horned cattle; for their support the social grasses were a necessary preliminary, and for the growth of these in sufficient abundance land naturally suitable for pasture was required. A further means of escape from man's growing difficulty in obtaining sufficient food was secured by aid of the cereal grasses, which supplied the means by which agriculture became the chief occupation of more civilised generations. Meanwhile, as these increased facilities for providing food were in turn overtaken by the growth of the population, new power to cope with the recurring difficulty had been gained through the invention of implements and weapons first of stone, and then of metal. Ultimately, the needful leisure was for the first time obtained for the cultivation of mechanical arts and of thought, when the earliest steps of civilisation had rendered the necessity for unremitting search after the

means of supporting existence less pressing; and thus was broken down the chief barrier in the way of progress, and man was carried forward to the condition in which he now is. The needful protection against the foes of his constantly increasing race—the legions of hunger and disease, infinite in number, ever changing their mode of attack or springing up in new shapes—could only be attained by some fresh adaptation of his organisation to his wants, and this took the form of that development of intellect which has placed all other creatures at his feet and all the powers of nature in his hand. But the marvellous growth of his knowledge, and his acquisition of the power of applying to his use all that lies without him, differ in nothing but form or degree from the earlier steps in his advance.

And man, with all his special faculties and dispositions, still remains, in most respects, as

directly dependent on the physical characteristics of the regions in which he dwells, as any other of the beings that possess the attribute of life. If, on one side, his ingenuity has enabled him to withstand the agencies which to other less sagacious animals were irresistible, and taught him how to wield them for his own purposes, yet on the other, while acquiring this power, he became physically more susceptible to their influences when they operate in a manner adverse to his well-being, and he is forced more completely than any other creature to shape his existence so as to conform to their inexorable sway.

Thus the progress of the human race towards civilisation has been controlled in all directions by the features and conditions of the earth's surface. The climate, temperature, and moisture, succession of the seasons, length of day and night, have gone far in determining the physical characteristics, the

bodily strength, and the duration of life in various races; and as less direct consequences, and under the greater or less necessity for the exercise of forethought in providing against vicissitudes of existence, have been developed their several capacities, social and intellectual, their numbers, wealth, and power.

The habits, modes of life, and occupations of all communities are immediately dependent on the features of the land where they dwell. The presence of a soil suitable for cultivation was one of the first necessities for progress; it has always remained one of the chief factors in the wealth of nations, and carries with it an agricultural population with fixed habitations. The pastoral and nomadic life is associated with upland pastures, or plains on which the soil or climate can provide only scanty grazing grounds. The varying vegetable, animal, and mineral products of

different lands and seas have supplied man with corresponding means of satisfying his wants or adding to his enjoyments, and hence, in each locality, his occupations and industries have had some special direction imparted to them. The neighbourhood of the sea gave birth to maritime pursuits, success in which largely depends on the character of the coasts, and the shelter afforded by their indentations. The distribution of mountain chains and valleys, of rivers and the basins they drain, the boundaries of land and sea, have controlled the extent of kingdoms, the intercourse, friendly or hostile, between different countries, the routes of commerce; they have supplied or withheld facilities for migrations, and protection against invasion. Within the limits they prescribe, states have become consolidated.

The ingenuity of man has only partially overcome the restraints thus put upon him.

The arts of civilisation have led to the transfer of the chief seats of his power from the warmer latitudes where existence is most easy, to colder climates where the conditions are more favourable to the continued exertion of his intelligence. To meet his demands, civilised man compels the earth to increase and vary its vegetable and animal produce by cultivation and domestication. He breaks into the store of minerals hid away below the surface and converts them into power. He turns night into day, and subdues the forces of heat and cold. He pierces the mountains; he spans the waters that stand in his path across the land, and cuts through the land that stands in his path across the waters. He makes the ocean a highway over which he rides, regardless of winds and waves, to pursue his ends in all parts of the earth, and to plant his colonies in distant countries; and thus uses an obstacle impassable

to most living things, as the principal means of his own migrations, and of supplying his constantly increasing wants and desires.

But with all his arts, man remains subject to the irresistible power of terrestrial conditions. History tells how, under the influence of causes that can be traced back to the material earth, the destinies of our race have been determined, nations have been born, have grown, have flourished, and have perished; for whether we call it mother-country or fatherland, the soil under our feet, as in the Greek fable, is the true source from which we draw our bodily, mental, and social strength.

The persistent efficacy of these influences is unmistakably shown by the little fundamental change that has taken place in the geographical areas within or around which the larger groups of human communities continue to be associated, notwithstanding

the greatly varied political conditions to which they have been subject. This is illustrated in most of the States of Europe. The Chinese empire still extends to what are virtually its ancient limits, and maintains its sway over a vast tract in Central Asia. The local distribution of the several elements of the population of India remains what it has been for several thousand years. In the new world fresh nationalities have replaced those destroyed by the Spaniards in Mexico, Peru, and Chili. The immigrant population of the United States in North America appears to have established itself in succession to the race that formerly spread over the same area. I cannot doubt that some of the political problems that have arisen in our own country at the present time will eventually be solved under the pressure of geographical necessity.

Nor are geographical influences on man limited to those of a material nature. The

constant succession of new objects which greets him as he changes his place on the globe, excites in him an interest not awakened by scenes of long-continued familiarity, and is one of the most active agencies in arousing his desire for knowledge. Thus too are multiplied those fields of observation which are the true and only sources from which he draws his intelligence and originality; for the mind has no power of absolute production, but only of perception and comparison. It is the faculty of applying with rapidity and precision the thoughts suggested by external objects and their mutual relations, that constitutes originality and gives the means of invention.

This is as true of imagination as of reason; by the influence and study of external nature are formed and developed man's emotional, intellectual, and moral faculties. The emotions created in the mind by the vast extent

of the ocean, its ever-moving surface, the broken outlines of land and sea, the richness and luxuriance of the vegetable clothing of the earth, the astonishing variety of animal forms, the many diverse races of men, the never-ceasing transformations of the clouds as they float overhead, the play of light and colour over the whole of these objects, the firmament set with stars, the unfathomable depths of space, the large serenity of nature at rest, her overwhelming violence in convulsion — emotions thus created are the source of all our ideas of the beautiful and sublime.

A knowledge of the relations that subsist among living beings, which is a direct result of geographical discovery, shows us man's true place in nature; our intercourse with other races of men in other countries teaches those lessons needed to overthrow the narrow prejudices of class, colour, and opinion, which

bred in isolated societies, and nourished with the pride that springs from ignorance, have too often led to crimes the more lamentable because perpetrated by men capable of the most exalted virtue.

In the review which I have thus attempted of the matters that in my judgment would be properly included in the geographical instruction to be undertaken by the University, it has been my aim to treat the subject with constant and almost exclusive reference to the necessary relation of all that is upon the earth with the features of the surface, which it is the fundamental business of geography to investigate and portray. A few words may, I think, be usefully added on the correlative aspect of the subject which regards geography as an art that supplies man, through a knowledge of the features of the surface and their dependent attributes, with practical

guidance in the affairs of life, or the advancement of other branches of learning.

A very small amount of consideration will show how intimately the geographical features of a country are bound up with the interests connected with it, and how important is a knowledge of those features, and their accurate delineation in maps.

The occupation of the earth's surface, from the elementary unit of the smallest field or humblest dwelling to the gradually increasing area of the estate, the parish, the county, and the kingdom, and thence to the largest continent, can be defined with precision only by the aid of maps; and much in proportion as correct maps have been applied to this end, disputes and complications in relation to property and jurisdictions have been avoided. Most of the difficulties arising from the extremely artificial system which secures titles to land in this country, and from the chaotic

distribution of local authorities extending over intersecting areas, would be removed, or would never have been created, if the commonest teachings of geography were respected. Many of the gravest differences that have arisen in modern times between England and foreign countries have been due to the neglect of the most simple and obvious means of defining boundaries by aid of proper maps. I think I shall not be far wrong if I attribute these results to the absence of a rational system of teaching geography to those who become our legislators and statesmen.

I have already said sufficient of the necessity for accurate maps in navigation. To the soldier, no less than to the sailor, maps and the power of making them, and understanding them rapidly and correctly, are essentials of the highest moment. The engineer is wholly dependent on exact representations of both the horizontal and

vertical features of the surface in many of his most important operations, and not less on a proper knowledge of the climate, the rainfall and the natural productions, mineral, vegetable, and animal, of the countries in which he is called on to carry out those operations. The physician must be possessed of a corresponding knowledge of the places to which he sends his patients in search of health, and must discriminate between the characteristics of climate due to geographical position and elevation above the sea-level. To the trader geography supplies information as to the condition of foreign countries to which he sends his merchandise, or from which he draws the commodities in which he deals; it will indicate the most convenient routes for commerce, and open the way to new markets, and to fresh fields from which to obtain articles of utility or luxury. From geography the emigrant seeks direction to a country

suited to his capacities and his constitution.

Geography furnishes the key by which to interpret many events of the past, and problems of the present, and supplies the rough materials from which to build up the great structure of natural science. Through its aid, moreover, an instrument of research, otherwise unattainable, may be to some extent provided for the study of physical phenomena. In dealing with many of these, no such control of conditions is within our power as that exercised in some branches of inquiry, whereby it is possible to verify conclusions by the aid of experiment, to vary the conditions of investigation at pleasure, and to draw inferences from the varying results under the changed conditions. But this want may be partly supplied, and a substitute obtained for the power of direct experiment, through observation of the effects produced

by the physical forces of nature, under the varied conditions that follow variation of geographical position on the globe.

The application of geographical considerations to the study of meteorology, which led to the use of synoptic charts exhibiting the atmospheric conditions at a given moment over a considerable area, was the immediate cause of the great advance in the interpretation of changes of weather that has taken place during the last fifteen or twenty years. The accumulation of knowledge from various countries, of various forms of life, and of the different conditions under which they are found, could only have been obtained by means of geographical exploration, and it was this, without doubt, that rendered possible the generalisations of Darwin and Wallace as to the origin and distribution of species.

I have now discharged the task that I

undertook. It remains for the University to carry out in a manner worthy of its reputation the objects which the appointment of a lecturer on geography is designed to meet. The instruction given will doubtless supply all needful corrections of the views I have advanced (for I am conscious of very insufficient knowledge of many parts of the numerous subjects to which it was necessary for me to refer), and fill in the outlines beyond which it has been impossible for me to go; supplying illustrations of the particular relations of the geographical conditions of the various parts of the earth with the chief classes of phenomena which they control or influence, whether falling within the range of natural science, history, or the economical interests of man, and keeping constantly before the student, by suitable examples, the necessary interdependence of all that is seen or done on the earth.

I am confident that by these means the University may become instrumental both in providing teachers better qualified to diffuse sound geographical knowledge through all classes of our countrymen, and in training travellers better able to extend that knowledge; objects which are among the special aims alike of the University and of the Society which I have the honour to represent.

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